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USER'S GUIDE FOR PEM-2:

POLLUTION EPISODIC MODEL (VERSION 2)

by

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The Pollution Episodic Model Version 2 (PEM-2) is an urban-scale model designed to predict short term average ground-level concentrations and deposition fluxes of one or two gaseous or particulate pollutants at multiple receptors. The two pollutants may be non-reactive, or chemically-coupled through a first-order chemical transformation. Up to 300 isolated point sources and 50 distributed area sources may be considered in the calculations. Concentration and deposition flux estimates are made using hourly mean meteorological data. Up to a maximum of 24 hourly scenarios of meteorology may be included in an averaging period.

The concentration algorithms used in PEM-2 are specially developed to account for the effects of dry deposition, sedimentation, and first-order chemical transformation. The Gaussian plume-type algorithms for point sources are derived from analytical solutions of a gradient-transfer model.

The User's Guide lists the concentration algorithms and computational techniques used in the PEM-2 program, and describes the input/output parameters, optional features, capabilities, and limitations of the model. Modifications to the previous version of the model are outlined. The information in the report is directed to the model user and the programmer.

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PREFACE

This report contains a technical description and complete user instructions for the Pollution Episodic Model Version 2 (PEM-2) computer program. The PEM-2 urban air quality dispersion model was developed to simulate the relevant physical processes in order to predict short-term ground level concentrations of particulate matter and/or gaseous pollutants from multiple point and area sources over an urban domain. Gaussian plume modeling techniques were adapted to allow for dry deposition processes by a gradient transfer approach and a chemical reaction between two species by a linear transformation method. The deposition and settling velocities for each species, and a transformation rate constant must be specified by the user. The model algorithms are subject to specific assumptions and limitations described in the report. PEM-2 is currently a non-guideline model.

Input requirements include source characteristics and emission rates, hourly measurements of meteorological parameters, and upwind boundary concentration. The latter should be representative of the incoming regional background measured sufficiently upwind of the urban emissions region. A comprehensive quality-assured emissions inventory and representative, accurate meteorological and concentration measurements aid in reducing model uncertainty.

The computer code has been thoroughly tested with example cases; however, errors are occasionally discovered and revisions may be made. Future revisions may be obtained if issued by completing and returning the form on the last page of this publication. Comments and questions about this publication should be directed to; Chief, Atmospheric Modeling Branch, Meteorology and Assessment Division (MD-80), Environmental Protection Agency, Research Triangle Park, NC 27711.

This user guide is available from the National Technical Information Service (NTIS), Springfield, VA 22161. The computer code is contained on the UNAMAP Version 6 magnetic tape and it may be obtained from Computer Products, NTIS, Springfield, VA 22161 (phone: (703) 487-4763).

ABSTRACT

The Pollution Episodic Model Version 2 (PEM-2) is an urban-scale model designed to predict short term average ground-level concentrations and deposition fluxes of one or two gaseous or particulate pollutants at multiple receptors. The two pollutants may be non-reactive, or chemically-coupled through a first-order chemical transformation. Up to 300 isolated point sources and 50 distributed area sources may be considered in the calculations. Concentration and deposition flux estimates are made using hourly mean meteorological data. Up to a maximum of 24 hourly scenarios of meteorology may be included in an averaging period.

The concentration algorithms used in PEM-2 are specially developed to account for the effects of dry deposition, sedimentation, and first-order chemical transformation. The Gaussian plume-type algorithms for point sources are derived from analytical solutions of a gradient-transfer model. In the limit, when deposition and settling velocities of the pollutants and the chemical transformation rate are zero, these expressions reduce to the familiar Gaussian plume diffusion algorithms. The concentrations from area sources in PEM-2 are calculated by numerical integration of the point source algorithms.

When the chemical transformation option is considered, PEM-2 calculates the average surface concentrations and deposition fluxes of both the primary (reactant) and the secondary (reaction product) pollutants. The model also permits a possible direct emission of the secondary pollutant. The deposition and settling velocities of the two species may be different. Either of the species may be a gaseous or particulate pollutant. PEM-2 is intended for studies of the atmospheric transport, transformation, and deposition of acidic, toxic, and other pollutants in urban areas to assess the impact of existing or new sources or source modifications on air quality for regulatory purposes and urban planning.

The User's Guide lists the concentration algorithms and computational techniques used in the PEM-2 program, and describes the input/output parameters, optional features, capabilities, and limitations of the model. Modifications to the previos version of the model are outlined. The information contained in this report is directed to the model user and the programmer.

This User's Guide to PEM-2 was prepared by NOAA's Atmospheric Turbulence and Diffusion Division in partial fulfillment of an Interagency Agreement with the U.S. Environmental Protection Agency. This work, covering the period December 1983 to July 1984, was completed as of September 30, 1984.

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Several figures and tables shown in this report are reproduced from the Users' Guide to Texas Episodic Model with permission from the Texas Air Control Board. The library routine D01AJF used for numerical integration in PEM-2 has been released by the Computer Sciences Division of the Oak Ridge National Laboratory for inclusion in the program listing. The Numerical Algorithms Group (NAG) holds the copyright to this routine and its document. The latter is reproduced in this report from the NAG FORTRAN Mini-Manual.

SECTION 1

MODEL OVERVIEW

1.1 INTRODUCTION

The Pollution Episodic Model Version 2 (PEM-2) is an urban-scale air quality model designed to predict short term ground-level concentrations and deposition fluxes of one or two, gaseous or particulate, reactive or non-reactive pollutants in an urban area with multiple point and area sources. PEM-2 uses the concentration algorithms developed by Rao (1982) which explicitly account for the effects of dry deposition, gravitational settling, and a first-order chemical transformation. These algorithms, derived analytically from a gradient-transfer model, are based on Gaussian plume modeling assumptions. For chemically-coupled pollutants, the surface concentrations and deposition fluxes of both the primary (reactant) and the secondary (reaction product) pollutant are calculated.

PEM-2 is based on the Pollution Episodic Model (PEM) developed by Rao and Stevens (1982). The latter, in turn, is based on the Texas Episodic Model Version 8 (TEM-8) developed by the Texas Air Control Board (1979) for the atmospheric dispersion of non-reactive pollutants over a perfectly reflecting (non-depositing) surface. In the limit, when the deposition and settling velocities and the chemical transformation rate are zero, the concentration algorithms used in PEM-2 reduce to the familiar Gaussian plume dispersion algorithms used in TEM-8. The two models share essentially the same framework for calculations, though there are differences in the computational techniques utilized in the models.

Besides the concentration algorithms, there are other important differences between PEM-2 and TEM-8 models:

1. PEM-2 uses Briggs' (1973) urban dispersion parameters for both point and area sources to represent 1-hour average dispersion. This treatment is similar to that used in EPA's RAM model (Turner and Novak, 1978). TEM-8 uses the Pasquill-Gifford (PG) curves to represent 10-minute average dispersion from point sources; for averaging periods longer than 10 minutes, the σ_y values are adjusted to account for the greater horizontal plume meander due to fluctuations in wind direction. For area sources, TEM-8 uses the σ_z's from Gifford and Hanna (1970) to represent 1-hour average dispersion.

2. PEM-2 determines the concentrations for a period longer than an hour by summing and averaging the concentrations calculated for each hour in the period. TEM-8 does not do this time-averaging for concentrations from area sources. Thus, with a constant meteorology for N hours, the area-source concentration at a receptor predicted by TEM-8 would be N times its hourly concentration.

3. TEM-8 estimates the point source concentrations by interpolating between the relative concentrations precalculated for selected values of model parameters and stored in large look-up tables. Because of the large number of model parameters, PEM-2 does not use this interpolation technique.

Other differences between these two models are listed in Section 3.

1.2 CAPABILITIES AND APPLICATIONS

The capabilities of PEM-2 are as follows:

1. PEM-2 is an urban-scale air quality model applicable to downwind distances of up to 50 km. Up to a maximum of 300 point sources and 50 area sources can be included in the model inputs to estimate concentrations at a maximum of 2500 receptors located on a 50 x 50 square receptor grid.

2. PEM-2 calculates short-term (1 to 24 hr) average ground-level concentrations and deposition fluxes of one or two gaseous or particulate pollutants.

3. The two pollutants may be non-reactive, or chemically-coupled through a first-order chemical transformation. If only one pollutant is calculated, the effects of a first-order chemical decay can be considered. The chemical transformation (or decay) rate may vary from 0.1 to 100 percent per hour.

4. The deposition (and settling) velocities of the two species may be equal or different. Direct emission of the secondary (reaction product) pollutant can be considered for both point and area sources.

Some areas of potential application of PEM-2 are the following:

1. Urban particulate modeling.

2. Studies of the transport, diffusion, transformation, and deposition of acidic, toxic, and other pollutants in urban areas. An important example is the atmospheric transport and transformation of SO_2 to $SO_4^=$.

3. Impact analyses of existing or new sources or source modifications for regulatory purposes and urban planning.

4. Stack design, and fuel conversion/switching studies. Evaluation of pollution control technology and strategies for prevention of significant deterioration.

1.3 ASSUMPTIONS AND LIMITATIONS

PEM-2 is based on steady state Gaussian plume modeling assumptions.

Some of the important assumptions of PEM-2 are as follows:

1. Concentration estimates may be made for each hour using the mean meteorological conditions for that hour. Average concentrations for a period longer than an hour are determined in the program by averaging the hourly concentrations of that period.

2. The sources are stationary and the emission rates are constant over the concentration-averaging period. The latter assumption is reasonable since PEM-2 is designed to predict only short-term average concentrations; this assumption is intended solely to limit the amount of input data required by the model.

3. If the hourly emission rates are highly variable over the concentration-averaging period, then the average concentrations may be obtained by averaging externally, with minimal programming, the concentrations calculated hourly and stored on tape by the model. This can be done, for example, to calculate the daily mean concentrations with diurnally varying emission rates.

4. Total concentration at a receptor is the sum of the concentrations calculated at the receptor from each source; i.e., concentrations are additive.

5. Pollutants released from a stack are transported downwind at a rate equal to the mean wind speed at the physical stack height. The wind direction is constant for each hour. The horizontal wind field is homogeneous and the effects of directional wind shear are neglected.

6. Diffusion of continuous plumes gives time-averaged Gaussian distributions for concentrations in the crosswind and vertical directions. The diffusion in the downwind direction is negligible compared to advection. This assumption obviously excludes calm conditions.

7. The reactant and the product species are coupled through a first-order chemical transformation. The deposition and settling velocities of the species, and the chemical transformation rate are constant over the concentration-averaging period. The diurnal variation of these parameters can be considered, if necessary, by averaging the hourly concentrations as discussed above.

8. Particulate pollutants consist of particles of a known size (or size distribution) with a representative settling velocity.

9. Pollutant concentration at a receptor due to the distributed area sources depends only on sources located in a narrow upwind sector. Therefore, horizontal diffusion can be ignored for area sources.

10. The crosswind variations of urban area source-strength patterns can be ignored. The contributions of more remote upwind area sources to the concentration at a receptor are quite small. For this reason, it is generally adequate to consider only eight area source grid squares immediately upwind of each receptor grid square.

Every air pollution model is limited by the assumptions used to predict the pollutant concentrations in the atmosphere. PEM-2 is subject to the same basic limitations as any Gaussian plume-type model. The limiting assumptions of the concentration algorithms developed for PEM-2 are discussed in detail by Rao (1982). Other general limitations of the model can be summarized as follows:

1. Receptors farther than 50 km downwind of a source are ignored. Thus the maximum downwind distance is limited to 50 km.

2. The number of point sources is limited to 300, and the number of area sources is limited to 50. The computer program can be easily modified by the user to increase the maximum number of point and/or area sources, if necessary. All sources are stationary.

3. The maximum number of scenarios (sets of hourly meteorological data) in an averaging period is limited to 24. PEM-2 is designed to calculate only short-term (1 to 24 hr) average surface concentrations and deposition fluxes of one or two pollutants.

4. PEM-2 does not make any adjustment for differences in terrain elevation between sources and/or receptors. The model assumes level terrain. No adjustments are made for building wake-induced downwash, wake entrainment, or other building-related effects on the various effluent plumes.

5. Only a first-order chemical transformation/decay is considered. The transformation rate, and the deposition and settling velocities of the species, must be specified by the user, if these options are selected.

6. The model cannot perform calculations for calm conditions; if such conditions occur, the wind speed is arbitrarily set to 1 m/s.

7. PEM-2 does not attempt to deal with wet removal processes; hence, the model does not apply during periods of precipitation.

1.4 SUMMARY OF INPUT DATA

Input to PEM-2 is divided into four main sections:

1) Control parameters

Control parameters remain constant throughout the model run. They specify:

1. An alphanumeric title
2. Time-averaging option
3. Options for types of input and output
4. Number of scenarios (sets of hourly meteorological data)
5. Options for using stack-tip downwash, new plume rise and new plume penetration schemes for point sources
6. Receptor grid coordinates and spacing
7. Automatic receptor grid option
8. Potential temperature gradient $d\theta/dz$ for calculation of plume rise with E and F atmospheric stability classes
9. Parameters for one or two pollutants:
    a) Deposition velocity
    b) Gravitational settling velocity
10. Option to calculate chemical transformation or decay of first pollutant
    a) Chemical transformation or decay rate
    b) Ratio of molecular weights of product to reactant
11. Scaling factors for area source emission rates
12. Calibration coefficients to be applied to the calculated concentrations

13. Alphanumeric labels for pollutants

14. Alphanumeric labels for the calibrated concentrations

15. Site-specific values of anemometer height and/or wind-profile exponents (optional)

2) Scenario Parameters

A scenario is a set of mean meteorological data for one hour. From one to twenty-four scenarios may be included in each run. Each scenario uses the same receptor grid and the same point and area source inventories. Meteorological parameters for each scenario are:

1. Atmospheric stability class
2. Wind speed class or specific wind speed
3. Wind direction sector or specific wind direction
4. Ambient temperature
5. Mixing height
6. Potential temperature gradient in the elevated stable layer above mixing height

3) Area Source Inventory

From zero to fifty area sources may be included in each run. Each area source square is described by:

1. Location in receptor grid coordinates
2. Length of a side
3. Emission rates for pollutants

4) Point Source Inventory

From zero to three hundred point sources may be included in each run. Each point source is described by:

1. Location in receptor grid coordinates
2. Emission rates for pollutants
3. Stack height

4. Inside diameter of the stack-tip
5. Exit velocity of the plume
6. Exit temperature of the plume
7. Alphanumeric identification

Details of the input data to PEM-2 are given in Section 4 of this report.

1.5 SUMMARY OF MODEL OUTPUT

For ease of reference, PEM-2 prints out and briefly explains all I/O control parameters and technical options used in a run. Input data for meteorological conditions, area sources, and point sources are also listed.

Calculated values of surface concentrations, deposition fluxes, and other useful information may be displayed in the following optional forms:

1. List Option --- For each receptor in the grid, the calculated values of concentrations and deposition fluxes are listed at the end of each averaging-period consisting of 1 to 24 scenarios.

2. Spatial Array Option --- The calculated values of concentrations and deposition fluxes at each receptor are displayed in map form at the end of each averaging-period.

3. Tape Option --- The calculated values of concentrations and deposition fluxes at each receptor are written on a magnetic tape (designated for output) at the end of each averaging-period. This option may be used to generate inputs to a contour-plotting routine, or to store hourly output data for averaging externally in order to account for the variability of hourly emission rates in an averaging-period consisting of more than one scenario (see Section 1.3).

4. Culpability List Option --- The five point sources which contributed most to the total concentration at each receptor are identified by point-source sequence number. A list of these source numbers and their percent contributions are printed for one or two pollutants at each receptor in the grid at the end of each scenario.

5. Maximum Concentration Option --- The maximum calculated values of surface concentration and deposition flux, and the receptor where these values occur, are printed for each pollutant at the end of the last scenario or averaging-period.

6. Point Source List Option --- The input stack parameters, the wind speed at physical stack height, the maximum effective source height, the dominant plume rise influence (buoyancy or momentum), and the plume penetration fraction (see Appendix B) are listed for each point source at the beginning of each scenario.

These output options are selected by the user by specifying appropriate values for the control parameters in the inputs to the model. It may not be possible to select some of these options in combination with others. The details are discussed in Section 4.

SECTION 2

TECHNICAL DISCUSSION

2.1 THEORETICAL BASIS

The concentration algorithms used in PEM-2 are derived from analytical solutions of a steady state gradient-transfer (K-theory) model, which describes the atmospheric transport, diffusion, deposition, and first-order chemical transformation of gaseous or particulate pollutants from an elevated continuous point source. The eddy diffusivity coefficients in these analytical solutions are expressed in terms of the empirical Gaussian plume dispersion parameters, so that the latter can be conveniently specified as functions of the downwind distance and the atmospheric stability class within the framework of the standard turbulence-typing schemes. The point-source concentration algorithms for the primary (reactant) and the secondary (product) pollutants are presented for various stability and mixing conditions of the atmosphere. In the limit when deposition and settling velocities and the chemical transformation rate are zero, these algorithms reduce to the well-known Gaussian plume dispersion algorithms presently used in EPA air quality models. Details of the gradient-transfer model formulations, analytical solutions, parameterizations, and development of the point-source concentration algorithms can be found in the reports by Rao (1981, 1982).

In PEM-2, the ground-level concentrations of the primary and secondary pollutants resulting from urban area source emissions are computed by numerical integration of the corresponding point-source concentration algorithms. The urban area-source modeling techniques of Gifford and Hanna (1970) are utilized in these computations. For point sources, PEM-2 provides options for using the standard or new plume rise formulations due to Briggs (1969, 1984), and new schemes for plume penetration of an elevated stable layer. For both point and area sources, PEM-2 uses the urban dispersion parameters of Briggs (1973) as given by Gifford (1976).

2.2 POINT SOURCES

2.2.1 Concentration Algorithms

The ground-level concentrations of the primary and the secondary pollutants (denoted by subscripts 1 and 2, respectively) from an elevated continuous point source are calculated in PEM-2 from one or both of the following sets of algorithms, depending on the atmospheric stability and mixing conditions:

Near-source region $(0 < x \leqq x_m)$,

$$C_1 = \frac{Q_1}{U} \cdot \frac{g_1}{L_y} \cdot \frac{g'_{21}}{L_z} \qquad \text{(1a)}$$

$$C_2 = \frac{Q_1}{U} \cdot \frac{g_1}{L_y} \cdot \frac{g'_{22}}{L_z} \qquad \text{(1b)}$$

Well-Mixed region ($x \geqq 2\ x_m$)

$$C_1 = \frac{Q_1}{U} \cdot \frac{g_1}{L_y} \cdot \frac{g'_{41}}{L} \tag{2a}$$

$$C_2 = \frac{Q_1}{U} \cdot \frac{g_1}{L_y} \cdot \frac{g'_{42}}{L} \tag{2b}$$

where $$L_y = \sqrt{2\pi}\ \sigma_y\ , \quad L_z = \sqrt{2\pi}\ \sigma_z \tag{3}$$

In the above, Q_1 is emission rate (source strength) of the primary pollutant, U is mean wind speed at physical stack height, L is mixing depth (height of inversion lid), x_m is the downwind distance (from source) determined such that $\sigma_z(x_m) = 0.47$ L, and L_y and L_z are length scales characteristic of diffusion in the horizontal crosswind and vertical directions, respectively. The nondimensional functions $g_1(\hat{x},\hat{y})$, $g'_{21}(\hat{x},0)$, $g'_{22}(\hat{x},0)$, $g'_{41}(\hat{x})$, and $g'_{42}(\hat{x})$, defined in terms of dimensionless parameterized variables, are given in Appendix A.

In Eqs. (1) and (2), it should be noted that the concentrations for both primary and secondary pollutants are expressed in terms of Q_1. This does not preclude consideration of a non-zero value for Q_2, the direct emission rate of the secondary pollutant. The algorithms for g'_{22} and g'_{42} provide for this possibility.

The well-mixed region algorithms, Eq. (2), are generally used under convective or neutral stability conditions. The ground-level plume centerline concentrations of the species in the plume-trapping region ($x_m < x < 2x_m$)

can be obtained by calculating the concentrations at x_m and $2x_m$ from Eqs. (1) and (2), and interpolating between these values on a log-log plot of concentrations versus downwind distance (Turner, 1970). PEM-2 uses this interpolation approach in the plume-trapping region.

2.2.2 Plume Rise

Plume rise is calculated from the standard or new equations given by Briggs (1969, 1984). The stack-exit conditions of the plume and the ambient temperature determine whether the upward motion of the plume is dominated by momentum or buoyancy. For atmospheric stability classes A to D, the unstable/neutral plume rise equations are used. For stability classes E and F, the stable plume rise equations are used. Thus, there are four different situations for plume rise:

(1) buoyancy-dominated plume in unstable/neutral atmosphere,
(2) momentum-dominated plume in unstable/neutral atmosphere,
(3) buoyancy-dominated plume in stable atmosphere, and
(4) momentum-dominated plume in stable atmosphere.

In each situation except the last one, the plume rise is calculated as a function of downwind distance from the stack until the final plume rise is attained. The standard plume rise equations for these four cases, the optional stack-tip downwash correction following Briggs (1973), and the crossover techniques used in PEM-2 to determine whether the plume is dominated by momentum or buoyancy are listed in Appendix B. The optional new equations of Briggs (1984) for estimating the maximum rise of a buoyancy-dominated plume in unstable/neutral atmosphere, and new schemes for plume penetration of an elevated stable layer are also given in this Appendix.

2.2.3 Dispersion Parameters

The Gaussian dispersion parameters, σ_y and σ_z, used in PEM-2 for each scenario are identical to those used in EPA's RAM model (Turner and Novak, 1978) to represent a 1-hour average dispersion over urban areas. Assuming a rectangular cross-section for the plume, Briggs (1973) gave interpolation formulas for these urban diffusion coefficients, which are based on the diffusion data from near-surface releases of a neutrally-buoyant tracer in St. Louis by McElroy and Pooler (1968). The corresponding expressions for σ_y and σ_z for a Gaussian plume, based on Briggs' formulations, are given by Gifford (1976, Figure 7, Table 8). Hosker (1973) compared these urban dispersion parameter curves to the Pasquill-Gifford (PG) σ curves, and showed that their values are greater than all but the more unstable of the corresponding PG curves because of the enhanced mechanical and convective turbulence over an urban area compared to that over open country.

PEM-2 uses the expressions for Briggs' urban dispersion parameters given by Gifford (1976). These formulas are written in a convenient form for programming as follows:

$$\sigma_z(x) = a_z x \quad (1+c_z x) \; (1+b_z x)^{-1/2} \tag{4a}$$

$$\sigma_y(x) = a_y x \quad (1+0.0004x)^{-1/2} \tag{4b}$$

In Eq. (4), x is given in meters. The coefficients a_y, a_z, b_z, and c_z are functions of atmospheric stability class, and their values are shown in Table 1.

TABLE 1

Values of Coefficients in the Formulas for $\sigma_y(x)$ and $\sigma_z(x)$, Equation (4), in Urban Conditions

P-G Stability Class	a_y	a_z	b_z	c_z
A-B	.32	.24	.001	.001
C	.22	.20	0	0
D	.16	.14	.0003	0
E-F	.11	.08	.0015	0

2.2.4 Restrictions on Receptors for Calculations

Pollutants emitted from each point source may not contribute to all of the receptors in a grid. The receptors excluded from the calculations are those located upwind of the source, too far from the plume centerline, or more than 50 km downwind of the source. For each source and each scenario, PEM-2 selects a rectangular area of the receptor grid downwind of the source, and calculations for that set of conditions are restricted to the receptors located within that area. The source contribution is considered to be zero at receptors located outside the area. Model inputs used for determining this area are the source coordinates, grid boundaries, wind direction, and the crosswind angle (Δ) between wind direction azimuth and the azimuth from the source to the receptor. If Δ exceeds the maximum crosswind half-angle of the plume (Δ_{max}), then the receptor is excluded from calculations. The values of the maximum crosswind half-angle used in PEM-2 for 1-hour averaging of the plume are shown in Table 2 as a function of the atmospheric stability class.

TABLE 2

Maximum Crosswind Half-angle Values

for Point Source Plumes

Atmospheric Stability Class	Δ_{max} (degrees)
A-B	43
C	33
D	25
E-F	18

At x = 100 m, these Δ_{max} values give a maximum plume half-width of 3 σ_y for calculations in the lateral direction. For x > 100 m, the maximum half-width of the calculated plume is larger than 3 σ_y.

2.3 AREA SOURCES

2.3.1 Emission Grid

PEM-2 defines a "calculation grid" by shifting the receptor grid to the South and to the West by one-half the side of a grid square ($\Delta x/2$). Thus each square in the calculation grid has one receptor at its center, since the calculation grid squares are of the same size (Δx) as the receptor grid squares.

Each area source used in PEM-2 should be sized so that it covers an integral number of calculation grid squares. The size Δx should be defined such that the smallest area source is at least as large as one calculation grid square.

The relationship between area sources and calculation grid squares can be divided into three cases. In the first case, the area source is of the same size as a calculation grid square. Emissions (Q_o) are assumed to be located at the center of the square; contributions of this area source are determined at the receptor (R_o) located at the center of the emission grid square, and at the receptors (R_1 to R_8) located at the center of each of the eight calculation grid squares immediately downwind of the source. This is schematically illustrated in Fig. 1, which shows only the first five receptors R_o,----, R_4.

The location of the eight downwind squares is not apparent in cases when the wind direction is not parallel to one of the calculation grid coordinate axes as shown in Fig. 2. The angle, ξ, between the wind azimuth and the nearest calculation grid coordinate axis is defined such that $0 \leqq \xi \leqq 45°$. PEM-2 considers ten ranges of values for ξ as shown in Table 3. For each range of ξ, the location of each downwind square is denoted by i (the number of calculation grid squares downwind from the area source) and j (the number of calculation grid squares off the axis used to define ξ), as illustrated in Fig. 2. These patterns of squares are stored in PEM-2 data tables that list values of i and j as shown in Table 3. For a given scenario, each area source will have the same spatial pattern of affected squares downwind.

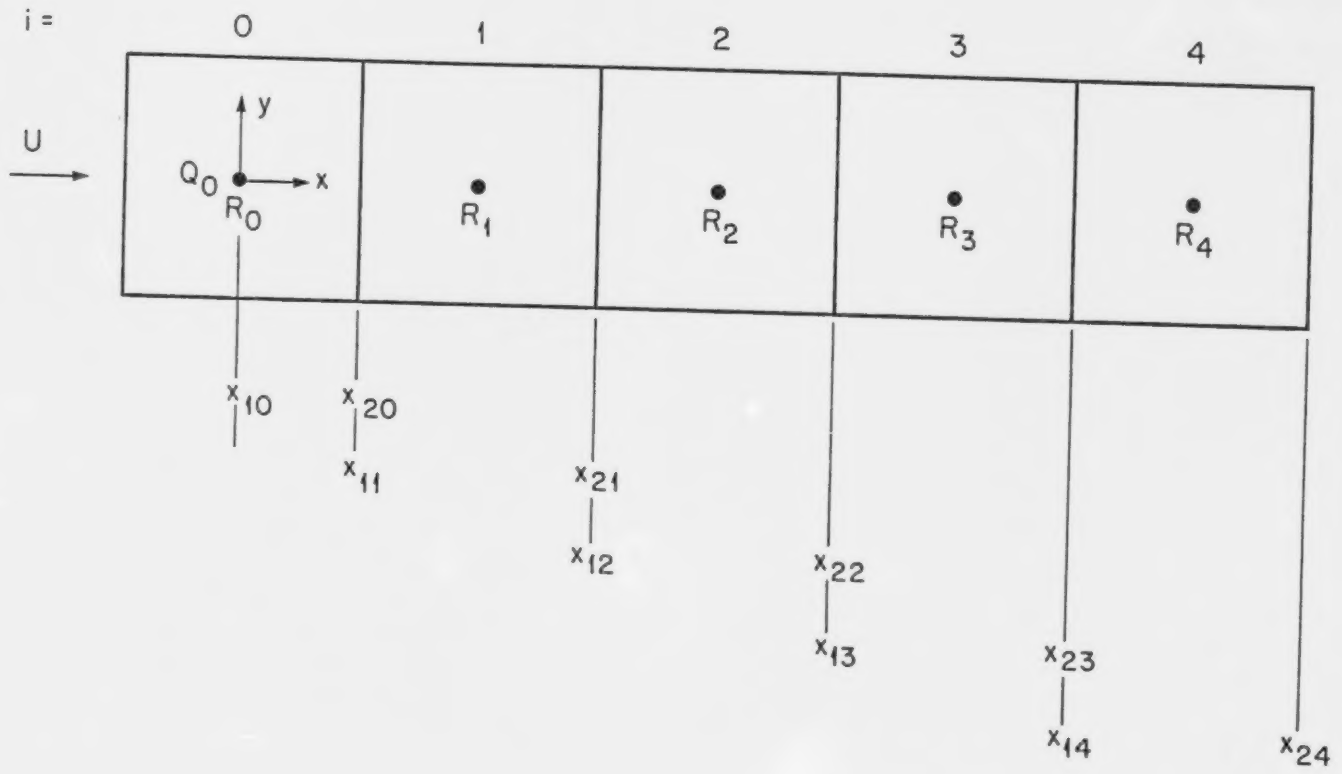

i =
0
1
2
3
4
U
y
x
Q_0
R_0
R_1
R_2
R_3
R_4
x_{10}
x_{20}
x_{11}
x_{21}
x_{12}
x_{22}
x_{13}
x_{23}
x_{14}
x_{24}

Figure 1. Schematic diagram showing a single grid square with emissions and four downwind calcuation grid squares with receptors, and the distances used in area-source algorithms. These distances are measured downwind from the source Q_o. PEM-2 considers eight downwind calculation grid squares (i.e., i=1,---,8) for each emission grid square (i=0).

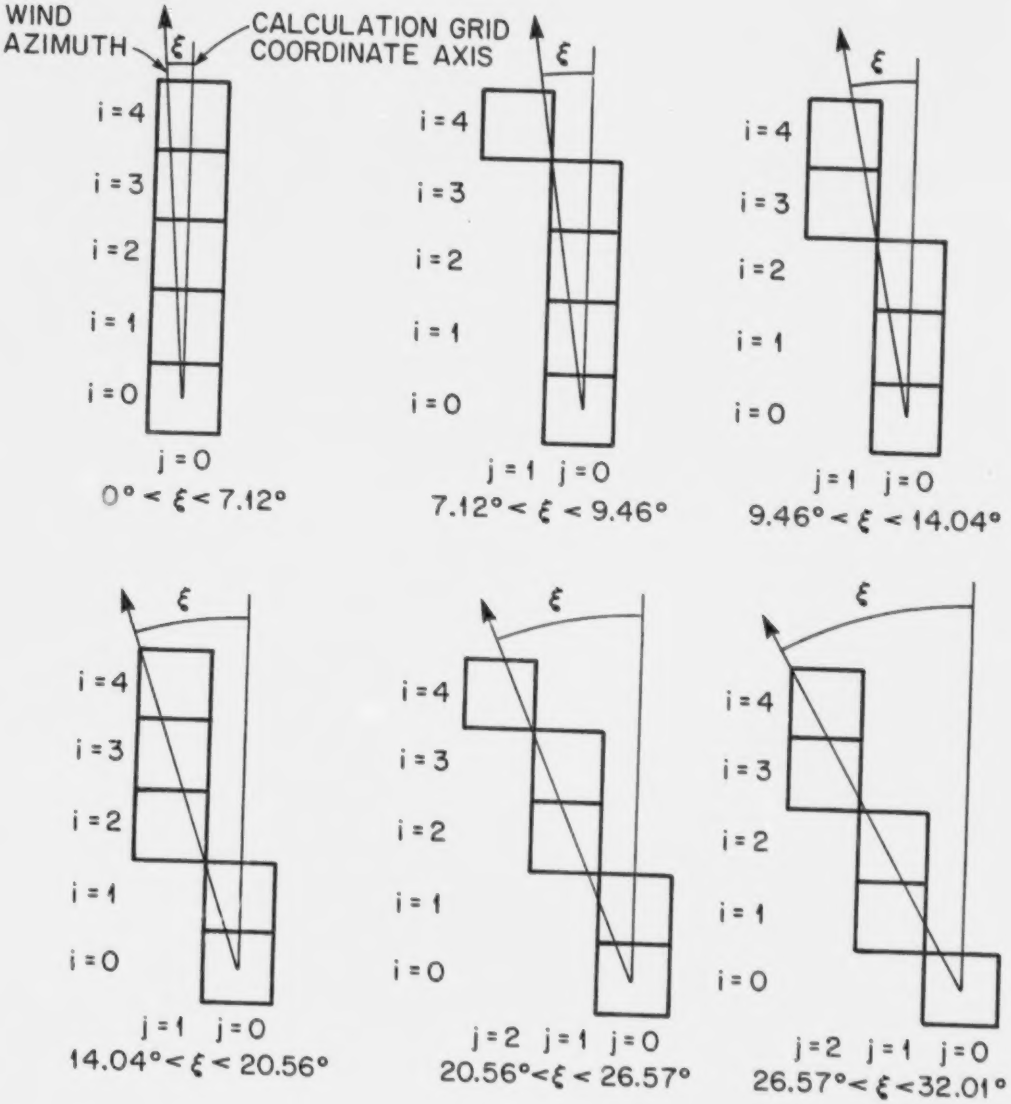
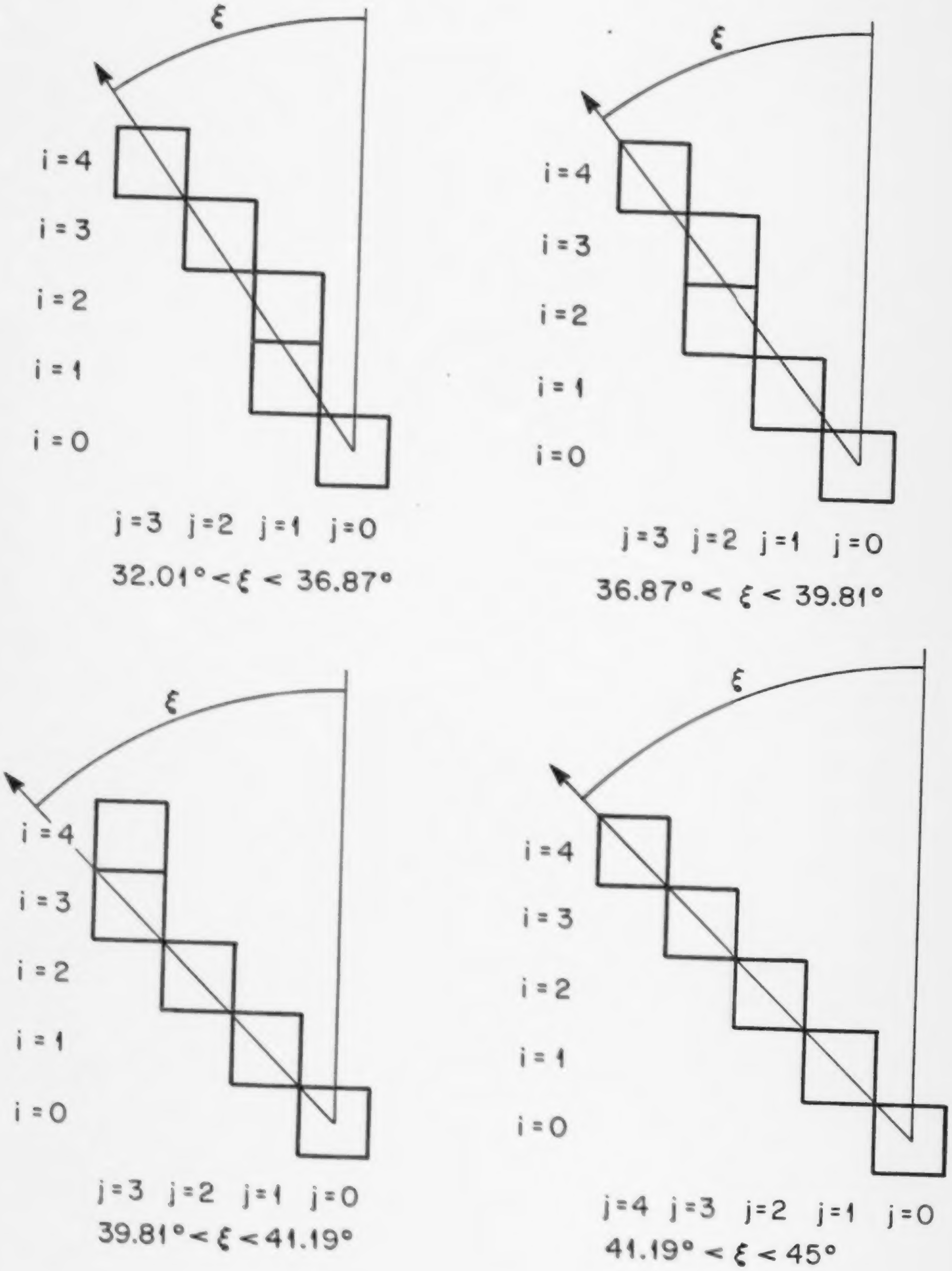

WIND AZIMUTH
ξ
CALCULATION GRID COORDINATE AXIS
i = 4
i = 3
i = 2
i = 1
i = 0
j = 0
0° < ξ < 7.12°
j = 1 j = 0
7.12° < ξ < 9.46°
j = 1 j = 0
9.46° < ξ < 14.04°
j = 1 j = 0
14.04° < ξ < 20.56°
j = 2 j = 1 j = 0
20.56° < ξ < 26.57°
j = 2 j = 1 j = 0
26.57° < ξ < 32.01°

Figure 2. Spatial patterns of affected calculation grid squares downwind of an area source. PEM-2 considers eight (i.e., i=1,---,8) affected grid squares downwind of an area source (i=0), though only the first four are shown in this figure.


ξ
i = 4
i = 3
i = 2
i = 1
i = 0
j = 3 j = 2 j = 1 j = 0
j = 4 j = 3 j = 2 j = 1 j = 0

$32.01° < \xi < 36.87°$

$36.87° < \xi < 39.81°$

$39.81° < \xi < 41.19°$

$41.19° < \xi < 45°$

Figure 2. Continued.

TABLE 3

Values of i and j for Each Spatial Pattern of Affected Squares Downwind of an Area Source

ξ range, degrees	Values for j**								
	i=0*	i=1	i=2	i=3	i=4	i=5	i=6	i=7	i=8
0 - 7.12	0	0	0	0	0	0	0	0	0
7.12 - 9.46	0	0	0	0	1	1	1	1	1
9.46 - 14.04	0	0	0	1	1	1	1	1	2
14.04 - 20.56	0	0	1	1	1	2	2	2	2
20.56 - 26.57	0	0	1	1	2	2	3	3	3
26.57 - 32.01	0	1	1	2	2	3	3	4	4
32.01 - 36.87	0	1	1	2	3	3	4	5	5
36.87 - 39.81	0	1	2	2	3	4	5	6	6
39.81 - 41.19	0	1	2	3	3	4	5	6	7
41.19 - 45.00	0	1	2	3	4	5	6	7	8

*i is the number of calculation grid squares downwind from the area source

**j is the number of calculation grid squares off the axis used to define ξ

For each value of ξ, a diagram of the first four affected squares downwind of an area source in square i=0, j=0 is shown in Figure 2.

In the second case, the area source is larger than one calculation grid square. Let m be the number of calculation grid squares covered by the source of area A. Then the emissions, Q, from the source are divided into m component emission rates defined by

$$Q_j = Q\, A_j/A \quad , \quad j = 1,2, \ldots, m$$

where A_j is the area of the source contained in the jth square,

$$A = \sum_{j=1}^{m} A_j \qquad \text{and} \qquad Q = \sum_{j=1}^{m} Q_j$$

Then the contributions from each of the m emission grid squares are determined following a procedure similar to that for a single emission grid square.

In the third case, a small area source may be imbedded in a large area source. The emission rate of the latter source is divided into components for each covered square as described above. Then each square is considered as an area source with an emission rate equal to the sum of the component emission rates from the original area sources.

2.3.2 Concentration Algorithms

The urban area sources consist of fugitive dust, highway, residential, commercial and industrial emissions, and their inventories are generally not detailed enough to provide information on the source height and plume-release conditions such as plume velocity, temperature, building wakes, etc. Furthermore, there are no reliable methods to estimate the plume rise from these distributed sources. Therefore, their emissions are generally assumed to be located at the ground-level (i.e., H=0) for simplicity. This assumption, however, may lead to calculation of large surface-concentrations, especially under light wind conditions when building wake-induced dispersion is less important and hot emissions from roof-top sources may have a rise comparable to the building height. The area-source concentration algorithms used in PEM-2 permit the user to specify a value of $H \geqq 0$ to represent the average effective height of emissions from the area sources in the inventory. This value of H is assumed to be constant for each concentration-averaging period.

The ground-level concentrations of the primary and secondary pollutants resulting from urban area source emissions in PEM-2 are computed by numerical integration of the corresponding point-source concentration algorithms. The urban area-source modeling techniques due to Gifford and Hanna (1970) are utilized in these computations. These techniques are based on the "narrow plume hypothesis," which postulates that the concentration at a receptor is influenced only by the distributed area sources located in a fairly narrow, plume-shaped upwind sector. This assumption allows one to ignore the lateral variation of concentration and the "end effects" due to the finite size of an area source grid; the concentration downwind of the center of the emission grid is then the same as that if the area source were infinitely wide in the crosswind direction.

We consider nine calculation grid squares (denoted by i=0, 1, 2, ----, 8), each with a receptor R_i located at its center. Figure 1 illustrates this schematically for the first five squares. The source emissions are assumed to be located at the center of the first square (i=0) upwind of the receptors. The emission rate of the primary pollutant from this single area source is Q_1. Then the ground-level concentrations of the primary and secondary pollutants, C_{A1i} and C_{A2i} respectively, at the receptor R_i in the ith calculation grid square downwind are obtained, following Rao (1982), by integrating the point-source concentration algorithms as follows:

$$C_{A1i} = \frac{Q_1}{U} \int_{x_{1i}}^{x_{2i}} \frac{g'_{21}(x, z=0)}{L_z} \, dx \qquad (5a)$$

$$C_{A2i} = \frac{Q_1}{U} \int_{x_{1i}}^{x_{2i}} \frac{g'_{22}(x, z=0)}{L_z} \, dx \qquad (5b)$$

The nondimensional functions g'_{21} and g'_{22} are defined in Appendix A, and $L_z = \sqrt{2\pi}\,\sigma_z$; x_{1i} and x_{2i} are distances measured from the center of the first square (i=0) to the upwind and downwind edges, respectively, of the calculation grid square with the ith receptor (see Fig. 1); U is the surface wind speed input to the model if the effective height of emissions $H \leq 10$ m, or the adjusted wind speed of $H > 10$ m (see Section 2.5.2).

The relative concentrations, UC_{A1i}/Q_1 and UC_{A2i}/Q_1, determined from Eq. (5) are independent of the emission rates of the species (except for the ratio Q_2/Q_1 which appears in g'_{22}) and their values at the receptors in the nine downwind calculation grid squares are calculated only once for each scenario. These relative concentrations are then multiplied by the emission rate Q_1 of each area source and U^{-1} to obtain the contributions to the concentrations C_{A1} and C_{A2} at each of the nine affected receptors. Note that, for a given scenario, each area source will have the same spatial pattern of affected receptors downwind. The contributions of all area sources affecting each receptor are summed to obtain the total concentration at that receptor.

In PEM-2, the integrations indicated in Eq. (5) are performed numerically by the trapezoidal rule together with Romberg's extrapolation method. Utilizing a maximum of 14 bisections of the interval (x_{1i},x_{2i}), this method computes an approximation for the integral to within 1 percent relative accuracy between successive approximations.

2.3.3 Dispersion Parameters

The dispersion parameters, σ_z, used in Eq. (5) for area-source concentrations are the same as those used for point sources (see Section 2.2.3). These dispersion coefficients, given by Briggs (1973) and Gifford (1976), account for the effects of increased surface roughness and heat flux in the urban environment, and are most representative for z_0 = 1 m and near-surface releases typical of the area sources.

2.4 RECEPTORS

2.4.1 Receptor Grid

PEM-2 calculates pollutant concentrations at each receptor in a rectilinear receptor array. A maximum of 2500 receptors may be used, with 50 columns and 50 rows. The spacing between each column and row is uniform, and is specified by the user. Receptors are located at the intersections of grid columns and rows. The grid spacing, number of columns, number of rows, and coordinates of the receptor at the southwest corner of the grid are used to define the grid.

Point and area sources need not necessarily be located within the grid boundaries. If area sources are included in the source inventory, the receptor grid spacing should be selected so that the smallest area source is of the same size as a grid square. An area source is positioned on the grid by specifying the coordinates of the southwest corner of the source. This corner should be located in the center of a receptor grid square, so that each square covered by the area source is centered on a receptor. For computations involving area sources, therefore, a calculation grid is defined with its grid squares the same size as receptor grid squares, but with a receptor located in the center of each calculation grid square. For details, see Section 2.3.1.

2.4.2 Automatic Grid Selection

PEM-2 has an optional subroutine which will automatically select a receptor grid for each scenario. The size and location of grids for different scenarios may differ since the selection of the receptor grid is based upon wind speed, wind direction, and atmospheric stability class.

Each source is examined sequentially. Two orthogonal axes are used with the origin located at the origin of the coordinate system for the point sources. The y axis is oriented in the north-south direction with positive values in the northerly direction. The x axis is oriented in the east-west direction with positive values in the easterly direction. Angle E is defined by

$$E = 90° - W$$

where W is the angle (measured relative to north) of the direction of the flow (see Fig. 3). The axes are then rotated through angle E such that the wind blows down the x axis. Negative values of E correspond to a clockwise rotation of coordinate axes; positive values correspond to a counterclockwise rotation.

For each scenario, the grid is automatically selected so as to provide good coverage by receptors near the point of maximum concentration. This point is estimated from the Gaussian plume concentration algorithm without the pollutant removal or transformation mechanisms. For a point source, the downwind distance to the point of maximum concentration, x_{m2}, is calculated from the equation

$$\frac{1}{\sigma_y}\frac{d\sigma_y}{dx} = \frac{1}{\sigma_z}\frac{d\sigma_z}{dx}\left[\frac{H^2}{\sigma_z{}^2} - 1\right] \qquad (6)$$

by the Newton-Raphson iterative method. In Eq. (6), H is the effective source height and σ_y and σ_z are the dispersion parameters given by Eq. (4). Equation (6) is derived by differentiating the expression for ground-level centerline concentration due to an elevated point source with respect to x, and equating it to zero.

Equation (6) is also used to determine x_{m1}, the point of maximum concentration using the physical stack height h_s instead of H. Then let

$$XTM(1) = XT + x_{m1}$$

$$XTM(2) = XT + x_{m2}$$

where XT is the x coordinate of the point source in the rotated coordinate system.

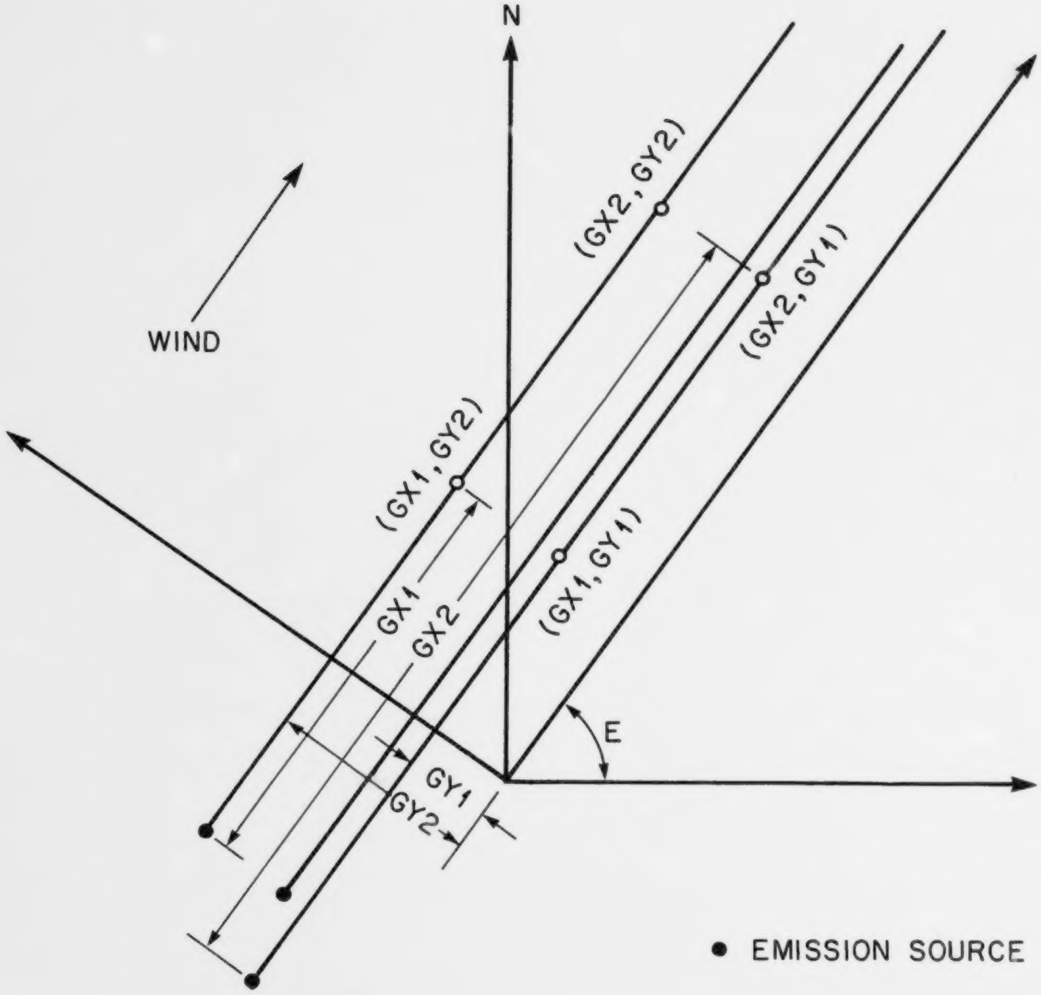

N
WIND
(GX2,GY2)
(GX2,GY1)
(GX1,GY2)
(GX1,GY1)
GX1
GX2
GY1
GY2
E
● EMISSION SOURCE

Figure 3. Points used for automatic selection of receptor grid by AUTGRD subroutine.

The largest value of XTM(2) for all point sources is GX2 and the smallest value of XTM(1) for all point sources is GX1. Let YT be the y coordinate of the point source in the rotated coordinate system. Then GY2 is the largest value YT for all point sources and GY1 is the smallest value of YT for all point sources. These points are illustrated in Fig. 3.

Next, the points (GX1, GY1), (GX2, GY1), (GX2, GY2) and (GX1, GY2) are rotated back to the original coordinate system. The largest of the four x values and the largest of the four y values are chosen for the coordinates of the northeast corner of the grid. The smallest of the four x values and the smallest of the four y values are chosen for the coordinates of the southwest corner of the grid.

Then XT is defined as the distance between the x coordinates of the grid corners and YT is the distance between the y coordinates of the grid corners. Let D_{max} be the larger of XT and YT. Then D_{max} is used to determine the number of columns and rows in the receptor grid and the grid spacing. If D_{max} is larger than 10 km, then the number of rows (or columns) is 50 and the grid spacing is XT/50 (or YT/50) km. If $5 < D_{max} < 10$ km, then a grid spacing of 0.2 km is used and the number of rows (or columns) is XT/0.2 (or YT/0.2). If $0.25 < D_{max} < 5$ km, then the number of rows (or columns) is 25, and the grid spacing is $D_{max}/25$. If $D_{max} < 0.25$ km, the grid spacing is 0.01 km, the smallest possible, and the number of rows (or columns) is XT/0.01 (or YT/0.01). A typical example of the receptor grid selected by the automatic grid option is illustrated in Fig. 4.

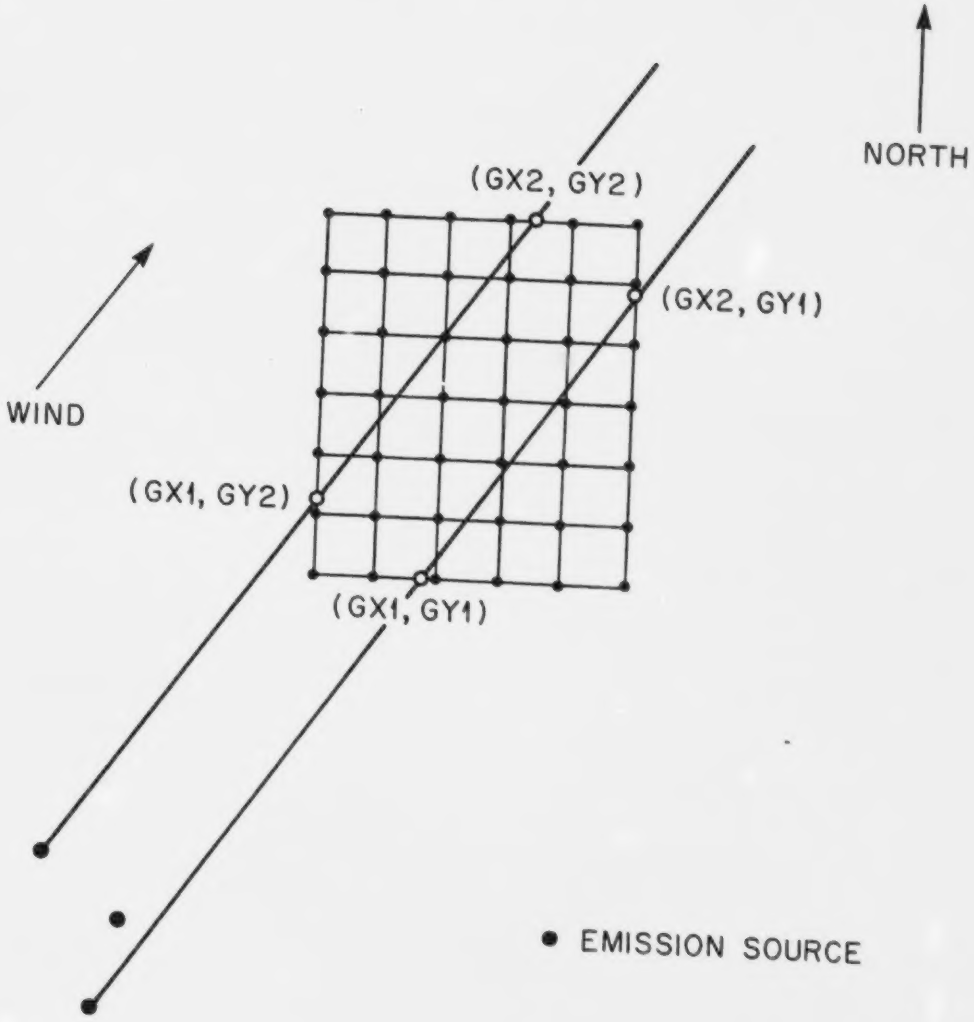

NORTH
(GX2, GY2)
(GX2, GY1)
WIND
(GX1, GY2)
(GX1, GY1)
● EMISSION SOURCE

Figure 4. Example of a receptor grid selected by AUTGRD subroutine.

If the culpability list option is elected in PEM-2, the receptor grid is limited to 25 rows and 25 columns. In this case, the grid spacing is increased so that the number of rows (or columns) does not exceed 25.

The automatic grid selection procedure, outlined above, considers only point sources. Therefore, the chosen receptor grid may not be suitable if area sources are included in the inventory. Furthermore, the point of maximum concentration determined from Eq. (6) may be in error for problems which include significant deposition, sedimentation, and chemical decay or transformation. The optimum receptor grid in this case should be determined by trial and error, using the receptor grid defined by this automatic grid option as the first approximation.

2.5 METEOROLOGY

The meteorological data used as input to PEM-2 consist of the atmospheric stability class index, wind speed, wind direction, ambient temperature, mixing depth, and the potential temperature gradient in the elevated stable layer. This data set, which represents the mean atmospheric conditions over an hour, is called a scenario. The maximum number of scenarios in an averaging period is limited to 24, i.e., PEM-2 is designed to predict only short-term (1 to 24 hr) average concentrations. When available, quality-assured on-site meteorological data are preferable to the National Weather Service (NWS) data.

2.5.1 Atmospheric Stability

The Pasquill-Gifford atmospheric stability classes used in PEM-2 are defined in Table 4.

TABLE 4

Atmospheric Stability Classes

Stability Class Index	Atmospheric Stability Class	Description of Conditions
1	A	Extremely unstable
2	B	Moderately unstable
3	C	Slightly unstable
4	D	Neutral
5	E	Slightly stable
6	F	Moderately stable

The relationship between the atmospheric stability classes and wind speed, incoming solar radiation, and cloud cover is given by Turner (1970) and shown below in Table 5.

TABLE 5

Atmospheric Conditions Defining Stability Classes

	Day			Night	
Surface Wind Speed (at 10 meters),m/s	Incoming Solar Radiation Strong	Moderate	Slight	Thin overcast or $\geq$4/8 low clouds	$\leq$3/8 cloud
<2	A	A–B	B	–	–
2–3	A–B	B	C	E	F
3–5	B	B–C	C	D	E
5–6	C	C–D	D	D	D
>6	C	D	D	D	D

Class A is the most unstable, while class F is the most stable class considered in PEM-2. Night refers to the period from one hour before sunset to one hour after sunrise. Note that the neutral class, D, should be assumed for overcast conditions during day or night, regardless of wind speed.

2.5.2 Wind Speed

PEM-2 gives the user an option for specifying either an hourly mean wind speed or the wind speed class number. The latter is based on National Weather Service (NWS) classification. Any wind speed which lies in a given range is assigned that class number; PEM-2 uses a representative wind speed for each class as shown in Table 6.

TABLE 6

Wind Speed Classification

NWS Wind Speed Class	Wind Speed Range (knots)	Representative Wind Speed (m/s)
1	0 - 3	1.50
2	4 - 6	2.46
3	7 - 10	4.47
4	11 - 16	6.93
5	17 - 21	9.61
6	> 21	12.52

Wind speed near the surface generally increases with height. Most NWS wind speed measurements are taken at a height (h_o) of 10 m above the surface and are listed as "ground-level" wind speeds (U_o) in knots. Then the wind speed (U) at the physical stack height (h_s) is determined as follows:

$$U = U_o (h_s/h_o)^p \tag{7}$$

The adjusted wind speed U is used (in meters/sec) in the plume rise calculations and the point-source concentration algorithms. Equation (7) is applied only when the stack height is greater than 10 m. The exponent p is a function of atmospheric stability class. The standard (default) values of p used in PEM-2 are shown in Table 7. For "ground-level" area source releases, the input wind speed (U_o) is used directly without any adjustment. If the effective height of area source emissions exceeds 10 m, then Eq. (7) is used to adjust the wind speed. For calm conditions ($U_o = 0$), the wind speed U_o is arbitrarily set to 1 m/s. However, since it is difficult to specify the wind direction under these conditions, it is better to remove "calm" hours from the input data.

TABLE 7

Values of Exponent p in Wind Speed Power Law

Atmospheric Stability Class	p
A = 1	0.15
B = 2	0.15
C = 3	0.20
D = 4	0.25
E = 5	0.30
F = 6	0.30

PEM-2 includes an option that allows the user to input site-specific values for h_o and/or p derived from local observations. The user should refer to Section 4.2.1 for details.

2.5.3 Wind Direction

By convention, wind direction is defined as the direction from which the wind is blowing. PEM-2 gives the user an option for specifying either an hourly mean wind direction, or the wind direction sector number based on the standard 16-point compass. Wind blowing from any angle in a 22.5° sector is assigned the number of that wind direction sector, and the wind direction is represented in the calculations by the median of that sector, as shown in Table 8.

TABLE 8

Wind Direction Sectors

Sector Number	Compass Point	Representative Wind Direction (deg)
1	N	0.0
2	NNE	22.5
3	NE	45.0
4	ENE	67.5
5	E	90.0
6	ESE	112.5
7	SE	135.0
8	SSE	157.5
9	S	180.0
10	SSW	202.5
11	SW	225.0
12	WSW	247.5
13	W	270.0
14	WNW	292.5
15	NW	315.0
16	NNW	337.5

PEM-2 also includes an option in which the user specifies the wind direction in degrees for the first of four sub-scenarios; for each succeeding sub-scenario, the wind direction is automatically shifted clockwise by 90, 45, 30, 15, 10, or 5 degrees depending on the option number specified in the input, while keeping the other meteorological parameters constant. Details of these I/O control parameters are given in Section 4.2.1.

2.5.4 Mixing Depth

The turbulent mixing layer near the ground is frequently bounded by a layer of stable air aloft. The latter effectively limits vertical dispersion to the mixing layer. The height of the base of the inversion above the ground is called the mixing depth, L. The hourly mixing depths are specified in the input to PEM-2.

If vertical mixing is limited, pollutants emitted from a point source into the mixing layer will be trapped and, beyond some point downwind, will become uniformly mixed in the vertical. PEM-2 uses different sets of concentration algorithms for the (near-source) mixing region and the well-mixed region. The concentrations in the intermediate plume-trapping region are then obtained by interpolation as described in Section 2.2.1. The determination of the mixing regime and the algorithms to be used in the model depend on the atmospheric stability class, mixing depth, effective height of the source, and the downwind distance.

If the physical stack height exceeds the mixing depth, pollutants are emitted in the stable layer aloft; these pollutants will not be brought to the ground level and the source is neglected.

If the physical stack height is less than the mixing depth, but the effective source height H exceeds L, then the plume may or may not escape the mixing layer. A buoyant plume rising into a convectively or mechanically mixed layer may partially or completely penetrate the capping stable layer, depending on the stratification strength and elevation of the latter with respect to the plume.

The default penetration scheme in PEM-2 does not allow partial penetration of the elevated stable layer. For $H \leqq L$, no penetration occurs; for $H > L$, complete penetration occurs and the source is ignored. However, PEM-2 includes optional new penetration schemes that consider the potential temperature gradient $\partial\theta_{ai}/\partial z$ in the elevated stable layer to estimate the extent of its penetration by a buoyancy-dominated plume in unstable/neutral atmosphere. The value of $\partial\theta_{ai}/\partial z$ is specified by the user in the meteorological data input to PEM-2; otherwise, a default value of 0.01°C/m (corresponding to an isothermal atmosphere) will be assumed in the calculations. The plume penetration schemes used in PEM-2 are discussed in detail in Appendix B.

SECTION 3

COMPUTER PROGRAM OVERVIEW

3.1 BASIS FOR PEM-2 PROGRAM

The PEM-2 computer program, listed in Appendix F, was developed by modifying the FORTRAN program of the Pollution Episodic Model (Rao and Stevens, 1982). The latter, in turn, was based on the computer program of the Texas Episodic Model Version 8 (TEM-8) and its Users' Guide (1979). TEM-8 uses the Gaussian plume concentration algorithms developed for nonreactive pollutants and a perfectly reflecting lower boundary. Chemical and physical depletion processes are therefore ignored, except for an option which allows a simple exponential decay of pollutant concentration with travel time. This method requires an accurate estimate of the pollutant's half-life.

In contrast, both PEM-2 and PEM explicitly account for dry deposition, gravitational settling, and a first-order transformation of two chemically-coupled gaseous or particulate pollutants in the concentration algorithms. The surface concentrations and deposition fluxes of both the primary pollutant (species-1 or reactant) as well as the secondary pollutant (species-2 or reaction product) are calculated. Thus, since PEM-2 accounts for these processes, the concentration algorithms used in PEM-2 and TEM-8 are different, though both models share essentially the same framework for calculations.

The PEM-2 model is developed from the PEM (Rao and Stevens, 1982) and the TEM-8 (Texas Air Control Board, 1979) with the following key modifications:

1. PEM-2 uses Briggs' (1973) urban dispersion parameters (based on the St. Louis diffusion data of McElroy and Pooler, 1968) for both point and area sources, whereas PEM and TEM-8 use power laws based on Pasquill-Gifford (PG) σ's for point sources and Gifford-Hanna (1970) σ_z's for area sources.

2. The number of atmospheric stability classes in PEM-2 are reduced to six, from seven in PEM and TEM-8, by combining the DD (neutral/day) and the DN (neutral/night) classes into a single D (neutral) class to conform with the current regulatory practice of the EPA.

3. For buoyancy-dominated plumes in unstable/neutral atmosphere, Briggs' (1984) new plume rise equations and plume penetration (of an elevated stable layer) schemes are included as optional features in PEM-2. On the other hand, PEM and TEM-8 use only the standard "all or none" criterion for determining plume penetration, and simulate inversions of various strengths by arbitrarily specifying an inversion penetration factor.

4. An option is provided in PEM-2 to use site-specific input values for the exponents of the wind-profile power law and anemometer height.

5. Concentrations from area source emissions (located at any effective height $H \geq 0$) are computed by numerical integration in PEM-2, while concentrations from area source emissions (assumed to be at ground-level) in PEM and TEM-8 are calculated from analytical concentration algorithms. The number of calculation grid squares used for each area source has been increased from 5 (in PEM and TEM-8) to 9 in PEM-2 to increase the calculated plume length and improve the model accuracy.

3.3 STRUCTURE OF THE PROGRAM

Figure 5 shows the structure of the PEM-2 computer program, its subroutines and functions. All input data to the model are read through subroutine INMOD. In order to calculate the relative concentrations of the species from area sources, the main program calls subroutine XINTEG to

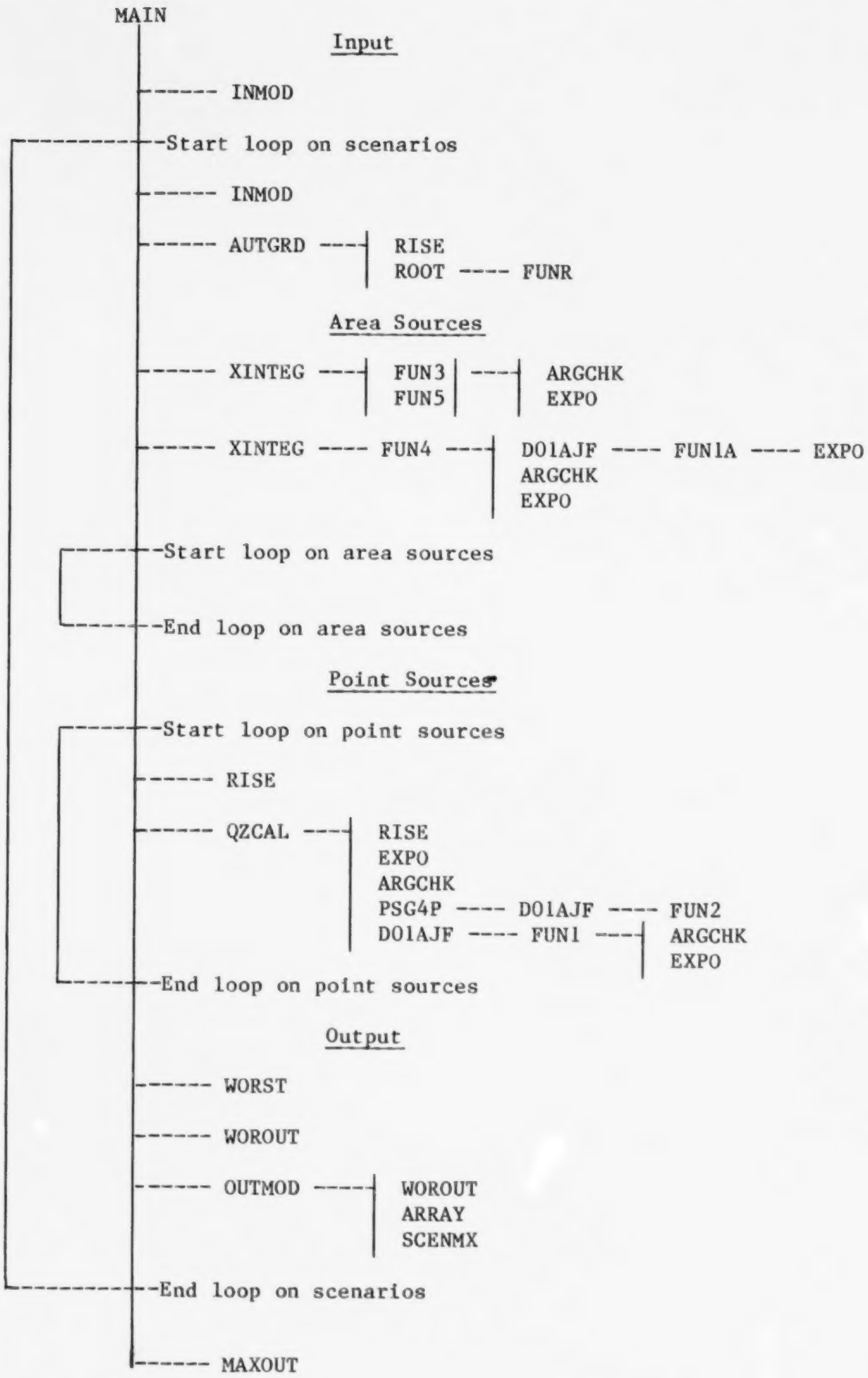

MAIN
Input
INMOD
Start loop on scenarios
INMOD
AUTGRD
RISE
ROOT
FUNR
Area Sources
XINTEG
FUN3
FUN5
ARGCHK
EXPO
XINTEG
FUN4
D01AJF
FUN1A
EXPO
ARGCHK
EXPO
Start loop on area sources
End loop on area sources
Point Sources
Start loop on point sources
RISE
QZCAL
RISE
EXPO
ARGCHK
PSG4P
D01AJF
FUN2
D01AJF
FUN1
ARGCHK
EXPO
End loop on point sources
Output
WORST
WOROUT
OUTMOD
WOROUT
ARRAY
SCENMX
End loop on scenarios
MAXOUT

Figure 5. Structure of computer program.

perform the numerical integrations. For each scenario, these numerical integrations are done only once, and each area source will have the same spatial pattern of affected squares downwind. These relative concentrations are then multiplied with the effective emission rates of the area sources to obtain the contributions to the concentrations at each receptor. After the area source calculations are completed, the program starts point source calculations by calling subroutines RISE and QZCAL. The latter calculates the probability densities of vertical distributions of concentrations of the two pollutants using the appropriate algorithms. All output is printed in subroutine OUTMOD, which calls and uses other optional output routines. This procedure is repeated for all scenarios.

3.3 GENERAL FLOW OF THE PROGRAM

At the beginning of the run, PEM-2 reads in all input data, screens them, prints warning messages, and sets default values as necessary. All control parameters are listed and explained. Input data for meteorological conditions, area sources, and point sources are also listed. Some errors in input data may be serious enough to cause cancellation of the run; however, in general, PEM-2 attempts to recover from input errors and complete the run using default values. The program prints an appropriate message whenever it resets an important input parameter to a default value.

Inventories of area and point sources must include the locations of the sources on a receptor grid, their emission rates, the size for area sources, and stack parameters for point sources.

These inventories are used with sets of hourly meteorological data called scenarios. For each scenario, the concentration and surface deposition flux are calculated at each impacted receptor in the grid.

Output options are many and varied. Concentration and surface deposition flux may be presented in the form of lists, array maps, or records on tape. Other options include a culpability list of point sources, and information on plume rise and effective stack heights for each scenario. At the end of the averaging period, a list of receptors with the highest concentration for each pollutant may be printed. The details of these I/O options are given in Section 4. The calculation of the surface deposition fluxes of the pollutant species is discussed in Appendix C.

SECTION 4

PROGRAM USER'S GUIDE

4.1 SUMMARY OF PROGRAM INPUT

Control Parameters (7 cards)

Control parameters remain constant throughout the run. They specify 1) a title; 2) run options for time-averaging, and types of input and output, and technical options for use of stack-tip downwash algorithm, new plume rise equations and plume penetration schemes; 3) receptor grid coordinates and spacing; 4) deposition and settling velocities of pollutants and an option to calculate chemical transformation or decay at a given rate; 5) scaling factors for area source emissions and calibration coefficients to be applied to the calculated concentrations; 6) labels for the pollutants and calibrations; and 7) an option for using site-specific values for wind-profile exponents and anemometer height.

Scenario Parameters (1-24 cards)

Each card contains information for one scenario; i.e., the meteorological data for one hour. It includes atmospheric stability class, wind speed, wind direction, temperature, mixing height, and potential temperature gradient in the elevated stable layer above the mixing height.

Area Source Parameters (0-50 cards)

Each card contains information for one area source. It includes the location of the area source on the receptor grid, the size of the area source, and its emission rates.

A blank card must follow the last area source card to signal the end of the area source data.

Point Source Parameters (0-300 cards)

Each card contains information for one point source. It includes the location of the point source on the receptor grid; its emission rates; the stack parameters of height, diameter, plume velocity and temperature; and a label which identifies the point source.

A blank card must follow the last point source card to signal the end of the point source data.

4.2 DETAILS OF PROGRAM INPUT

4.2.1 Control Parameters (7 cards)

Card 1 : Title FORMAT (20A4)

Information identifying the run, which is printed at the top of each page of output. Up to 80 alphanumeric characters are allowed.

Card 2 : Input and output options FORMAT (18I4)

NTOPT Averaging time option

=1 One hour: Concentrations are calculated for each scenario. No averaging done.
=2 Twenty-four hours: Concentrations are calculated for exactly 24 scenarios and averaged.
=3 Variable (2 to 23 hours): Concentrations are calculated for a given number of scenarios and averaged.

The default value is NTOPT = 1 .

NWDOPT Wind direction input option

=0 The user will specify wind direction in degrees for each scenario.
=1 The user will specify a wind direction sector number (from 1 to 16) for each scenario.
=2-7 The user will specify wind direction in degrees for the first of four sub-scenarios. For each succeeding sub-scenario, the wind direction is automatically shifted clockwise by 90, 45, 30, 15, 10, or 5 degrees for option numbers 2, 3, 4, 5, 6, and 7, respectively. NWDOPT = 2-7 is not allowed with time-averaging, i.e., when NTOPT = 2 or 3 .

The default value is NWDOPT = 0 .

NWSOPT Wind speed input option

=0 The user will specify surface wind speed in meters/sec for each scenario.
=1 The user will specify a wind speed class number (from 1 to 6) for each scenario.

The default value is NWSOPT = 0 .

NWPOPT Wind-profile exponents input option

=0 The model uses the standard (default) values for the urban wind-profile exponents. The anemometer height for surface wind observations is assumed to be 10 m.

=1 The user will input site-specific values for wind-profile exponents and anemometer height on Card 7.

The default value is NWPOPT = 0 .

NSCEN Number of scenarios

=1-24 The number of sets of hourly meteorological data to be read and processed by the program. If NTOPT=2 is specified, then NSCEN must equal 24 . If NSCEN is not specified correctly, then either the input data file will be misread or the run will be terminated.

The default value is NSCEN = 1 .

NLIST Output option for printing lists of uncalibrated concentration and surface deposition flux, and calibrated concentration at each receptor in the grid.

=0 The lists are not printed.

=1 Lists of concentration and surface deposition flux are printed, for one or two pollutants, at grid receptors with uncalibrated concentrations of at least 1 microgram per cubic meter.
NLIST = 1 may not be used with the automatic windshift option (NWDOPT > 1) .

The default value is NLIST = 0 .

NARRAY Output option for array maps of calculated concentration and surface deposition flux at each receptor in the grid.

=0 No array maps are printed.

=1 Separate maps of uncalibrated concentration and surface deposition flux, and calibrated concentration are printed --- a total of three maps for each pollutant.

=2 Maps of uncalibrated concentration and surface deposition flux are printed --- two maps for each pollutant.

=3 Maps of calibrated concentration and surface deposition flux are printed --- two maps for each pollutant.

The default value is NARRAY = 0 .

NTAPE Tape output option for a list of both uncalibrated and calibrated concentrations and surface deposition fluxes at each receptor in the grid.

=0 The list is not written on tape.

=1 A list of concentrations and deposition fluxes is written on a separate output tape, one receptor per record. Control parameter INTER may be set to limit the number of receptors written on tape. The program checks the total number of records to be written; if the number is greater than 62500, a message is printed and NTAPE is set to zero.

NTAPE=1 may not be used with the automatic windshift option (NWDOPT > 1). NTAPE=1 may be used with NTOPT=1 to store the hourly concentrations, in order to calculate average concentrations externally for problems with highly variable emission, transformation, and deposition rates (see Section 1.3).

The default value is NTAPE = 0 .

NCSOPT Output option for a culpability list of the five point sources which contribute most to the total concentration calculated at each receptor.

=0 The culpability list is not printed.

=1 For each receptor in the grid, the program lists up to five point sources and the percentages of total concentration contributed by these sources. The total concentration and surface deposition flux at each receptor are also listed. This information is printed, for one or two pollutants, only at receptors with the highest contributions exceeding 1 microgram per cubic meter. NCSOPT=1 can be used only with NTOPT=1 . This option may not be used for more than one scenario with the automatic windshift option (NWDOPT>1). It also may not be used when the number of columns (LX) or the number of rows (LY) in the grid is greater than 25 .

The default value is NCSOPT = 0 .

NMAX Output option for listing the maximum concentration and surface deposition flux calculated for each pollutant.

=0 The lists are not printed.

=1 At the end of the run, for each scenario or averaging period, lists are printed to show the receptor which received the highest concentration and deposition flux for each pollutant.

The default value is NMAX = 0 .

NSTDWN Technical option for stack-tip downwash algorithm for point sources.

=0 The stack-tip downwash algorithm is used in the program to include the downwash effects.

=1 The downwash algorithm is not used.

The default value is NSTDWN = 0 .

NPRISE Technical option to use Briggs' new equations for maximum rise of buoyancy-dominated plumes from point sources.

=0 Standard Briggs' plume-rise equations are used for all stability classes.

=1 New equations are used for maximum plume rise of buoyancy-dominated plumes for stability classes A-D (unstable/neutral atmosphere).

The default value is NPRISE = 0 .

NINPEN Technical option to use new schemes for penetration of buoyancy-dominated plume above mixing height.

=0 Standard "all or none" criterion for plume penetration above mixing height is used.

=1 New schemes are used for buoyancy-dominated plume penetration of elevated stable layer for stability classes A-D (unstable/neutral atmosphere).

The default value is NINPEN = 0 .

INTER Output option for interval of receptors written on tape.

=N When the output option NTAPE=1 is selected, the value of INTER determines which receptors are written on the tape. When INTER is specified as integer N, every Nth receptor in each column and row is listed. Thus, if INTER=2, one fourth of the receptors will be listed; if INTER=5, one twenty-fifth will be listed. Effectively, an output grid is set up with "new" spacing equal to the value of INTER*GRID, and only those receptors on the "new" grid will be listed on the tape.

The default value is INTER = 1 .

NPRINT Output option for point source information.

=0 Input point source data is printed only at the beginning of each run.

=1 A list of input point source parameters and calculated plume rise information is printed for each scenario.

The default value is NPRINT = 0 .

INPTSC Input option for point source data.

=1 Point source data is read from the normal input stream (on cards, for example).

=2 Point source data is read from a disk file specified by the user.

The default value is INPTSC = 1 .

NGPR	Gradual plume rise option for point sources.
=0	Gradual plume rise used close to point source(s).
=1	Final effective plume rise height used for all distances.
NBID	Option to consider bouyancy induced dispersion (BID).
=0	BID is not used.
=1	BID is considered for elevated point sources.

Card 3 : Grid information FORMAT (2F10.0,2I10,3F10.0)

XRSWC	The x, or east-west coordinate of receptor at the southwest corner of the grid, in kilometers. The default value is XRSWC = 0.0 .
YRSWC	The y, or north-south coordinate of receptor at the southwest corner of the grid, in kilometers. The default value is YRSWC = 0.0 .
LX	The number of columns of receptors in the grid. Allowable values are 1 to 50 . The default value is LX = 1 .
LY	The number of rows of receptors in the grid. Allowable values are 1 to 50 . The default value is LY = 1 .
GRID	Automatic grid option or grid spacing.
=0.0	The program designs the receptor grid for each scenario such that there is good receptorcoverage near the point of maximum concentration. For point sources, this location is determined from the Gaussian plume algorithm without deposition or transformation. For problems that include these removal mechanisms and area source emissions, therefore, this automatic grid may not be the optimum grid. This option cannot be used when NTOPT > 1 .
>0.0	The size of the spacing between columns and rows of receptors in the grid, in kilometers. The default value is GRID = 0.0 .
DTDZ(1), DTDZ(2)	The atmospheric potential temperature gradient for E and F stability classes, respectively, in deg. C/meter. These values are used in the plume

rise equations under stable conditions.
The default values are DTDZ(1) = 0.02 and
DTDZ(2) = 0.035 .

Card 4 : Pollutant deposition and chemical transformation parameters FORMAT (2I5, 6F10.0)

NPOL The number of pollutants (1 or 2)
The default value is NPOL = 1 .

ICT Chemical transformation or decay option.
=0 Transformation/decay of pollutant-1 is ignored.
=1 If NPOL = 1, a first-order chemical decay of the pollutant-1 is considered.
If NPOL = 2, a first-order chemical transformation of pollutant-1 to pollutant-2 is considered.
The default value is ICT = 0 .

VD1 Deposition velocity of pollutant-1, in cm/sec.

W1 Settling velocity of pollutant-1, in cm/sec.

VD2 Deposition velocity of pollutant-2, in cm/sec.

W2 Settling velocity of pollutant-2, in cm/sec.

The default values of W and VD for both species are zeros. If either W or VD is less than 0.01 cm/sec, then the value of that parameter is set to zero. This reduces computer run times and job costs without significantly altering the calculated concentrations.
In general, for deposition to occur, the settling velocity (W) should be less than or equal to the deposition velocity (VD). For gases and very small particles, W should be zero. For small particles, W should be less than VD. For particles of size d > 50 microns, W should equal VD.

XKT Chemical transformation or decay rate of pollutant-1 , in percent/hour. Allowable values are 0.1 to 100.0 ; input values outside this range are set to the nearer limit. For example, if XKT=0.0 is specified (when ICT=1), then the program prints a message and sets XKT=0.1 .

GAMMA The ratio of molecular weights of pollutant-2 (product) to pollutant-1 (reactant) in the chemical transformation (when ICT=1).
The default value is GAMMA = 0.0 .

Card 5 : Scaling and calibration FORMAT (7F10.0)

HAS	The effective height of area source emissions in meters. Note that a single value is used to approximate the height of emissions from all urban area sources. The default value is HAS = 0.0 .
ASCALE(1), ASCALE(2)	Area source scaling factors for pollutants 1 and 2. All area source emission rates are multiplied by ASCALE(1) for pollutant-1 and by ASCALE(2) for pollutant-2. These factors may be utilized to scale the entire area source inventory to account for higher emission rates expected in future years (from an increased traffic volume, for example), or to convert the units of emission rates in the inventory to grams/sec. The default values are ASCALE(1) = 1.0 and ASCALE(2) = 1.0 .
A(1), B(1)	Coefficients used to calibrate the calculated concentration of pollutant-1. The calibrated concentration, C^* , is computed from the formula $C^* = A + B . C$, where C is the uncalibrated concentration. The normal output units of the latter are micrograms per cubic meter. The calibration coefficients can be used to convert the units to percent allowable, parts per million, or any other convenient units. The default values are A(1) = 0.0 and B(1) = 0.0 .
A(2), B(2)	Coefficients used to calibrate the calculated concentration of pollutant-2. The default values are A(2) = 0.0 and B(2) = 0.0 .

Card 6 : Labels FORMAT (3A4,7A4,3A4,7A4)

POLNAM(1)	Name for pollutant-1 Up to 12 alphanumeric characters are allowed.
CALNAM(1)	Label for calibrated values of concentration of pollutant-1, computed from calibration coefficients A(1) and B(1). Up to 28 alphanumeric characters are allowed.
POLNAM(2)	Name for pollutant-2 Up to 12 alphanumeric characters are allowed.
CALNAM(2)	Label for calibrated values of concentration of pollutant-2, computed from calibration coefficients A(2) and B(2). Up to 28 alphanumeric characters are allowed.

Defaults for all labels are blanks.

Card 7 (optional): Site-specific values of anemometer height and/or wind-profile exponents FORMAT (10F7.0)

HA	Anemometer height of wind speed measurement in meters. This is the height at which the surface wind speed is measured. The default value is HA = 10.0 .
HMIN	Wind speed held constant below this height in meters. Default value is HMIN = 10.
HMAX	Wind speed held constant above this height in meters. Default value is HMAX = 200.
UMIN	Wind speed not allowed less than this value (meters/s). Default value is UMIN = 1.0
P1(I), I=1,6	Wind profile exponents derived from local observations for stability classes 1 to 6 . The default values are given in Section 2.5.2.

Note that site-specific values for anemometer height and/or wind-profile exponents can be specified only if the wind-profile option NWPOPT on Card 2 is specified as NWPOPT=1.

4.2.2 Scenario Parameters FORMAT(3I5,5F10.0)

One to 24 cards, each containing a set of meteorological data for one hour.

NSC	Atmospheric stability class number Allowable values are 1 to 6 ; an input value outside that range will be set to the nearer limit.
NWS	Wind speed class Allowable values are 1 to 6 ; an input value outside that range will be set to the nearer limit. Note that NWS is used only when the windspeed input option NWSOPT on Card 2 is specified as NWSOPT=1 .
NWD	Wind direction sector Allowable values are 1 to 16 ; an input value outside that range will be set to the nearer limit. Note that NWD is used only when the wind direction input option NWDOPT on Card 2 is specified as NWDOPT=1 .
WS	Surface wind speed in meters/sec This is assumed to be measured at a height of 10 meters unless a different value for anemometer height is specified on Card 7 above. Note that WS is used only when the wind speed input option NWSOPT on Card 2 is specified as NWSOPT = 0 . If WS=0.0 (calm) is specified

under this option, a message is printed and WS is set to 1.0 meter/sec.

WD	Wind direction The azimuthal angle in degrees of the direction from which the wind is blowing. Allowable values are 0.0 through 360.0 degrees. Note that WD is used only when the wind direction input option on Card 2 is specified as NWDOPT=0 or 2 through 7. The default value is WD = 0.0, wind from the north.
TA	Ambient temperature at 10 m height in deg. C. The default value is TA = 0.0 .
HMIX	Mixing height in meters The height of the base of the inversion above the ground. This is also effectively the depth of the turbulent mixing layer. The default value is HMIX = 9999.99 .
DTDZI	Potential temperature gradient in the elevated stable layer above mixing height in deg. C/meter. The default value is DTDZI = 0.01 .

4.2.3 Area Source Parameters FORMAT(5F10.0)

Zero to 50 cards, each containing parameters for one area source. A blank card must follow the last area source data card.

XA	The x, or east-west, coordinate of southwest corner of the area source, in kilometers. The default value is XA = 0.0 .
YA	The y, or north-south, coordinate of southwest corner of the area source, in kilometers. The default value is YA = 0.0 .
SIZE	The length of a side of area source in meters. The default value is SIZE = GRID*1000.0, the side of a receptor grid square in meters. If GRID=0.0 (i.e., automatic grid option is elected), then SIZE is arbitrarily set to 1.0 .
EA(1), EA(2)	Emission rates for pollutants 1 and 2 in gms/sec. Note that EA is not an emission rate per unit area; this is the emission rate of an equivalent point source located at the center of the area source. The default values are EA(1) = 0.0 and EA(2) = 0.0 .

Note that area source inventory must be followed by a blank card to signal the end of area source data.

4.2.4 Point Source Parameters FORMAT(8F9.0, 2A4)

Zero to 300 cards, each containing parameters for one point source. A blank card must follow the last point source data card.

XP The x, or east-west, coordinate of point source, in kilometers.
The default value is XP = 0.0 .

YP The y, or north-south, coordinate of point source, in kilometers.
The default value is YP = 0.0 .

EP(1), EP(2) Emission rates for pollutants 1 and 2 in gms/sec.
The default values are EP(1) = 0.0
and EP(2) = 0.0 .

HP The physical height of the stack in meters.
The default value is HP = 0.0 .

DP The inside diameter of the stack-tip in meters. If DP=0.0 is specified, a message is printed and DP is set to 1.0E-4 meters.

VP The stack-exit velocity of plume in meters/sec.
The default value is VP = 0.0, which results in zero plume rise.

TP The stack-exit temperature of plume in deg. C.
The default value is TP = 0.0 , which usually results in a momentum-dominated plume rise.

NAME Label which identifies the point source. Up to eight alphanumeric characters may be used.
The default is blanks.

Note that the point source inventory is followed by a blank card to signal the end of the point source data.

4.3 GUIDE TO PROGRAM OUTPUT

PEM-2 has several output options which are outlined below. In order to avoid a large output, the user may select only the necessary options on Card 2.

NPRINT ---- Point source information

At the beginning of each scenario or sub-scenario*, for each point source, the output lists its coordinates on the receptor grid, emission rates, stack parameters, dominant influence (momentum or buoyancy) of plume rise, wind speed at physical stack height, maximum effective source height, and plume penetration fraction (see Appendix B).

NCSOPT --- Point source culpability list

At the end of each scenario or sub-scenario*, for each receptor in the grid, the five point sources which contributed most to the total concentration at that receptor are identified. For each receptor, the output includes the five point-source sequence numbers, the percentage of total concentration each of the five produced, and the total concentration and surface deposition flux at the receptor. This information is printed for one or two pollutants. To reduce the amount of output produced, only receptors with highest contributions exceeding 1 microgram per cubic meter are printed.

NLIST --- Concentration and surface deposition flux list

At the end of an averaging-period consisting of 1 to 24 scenarios, the uncalibrated concentration and deposition flux, as well as the calibrated concentration, of one or two pollutants are listed at each receptor in the grid. To reduce the amount of output produced, only receptors with uncalibrated concentrations of at least 1 microgram per cubic meter are listed.

NTAPE --- Concentration and surface deposition flux tape

At the end of the averaging-period, for each receptor in the grid, the calculated concentration and surface deposition flux are written on to a separate output tape. All records on the tape contain eighty alphanumeric characters. A separate record is written for every receptor in the grid, unless the interval parameter INTER has been specified as greater than one. The first record on the tape contains the title information given on Card 1 of the Control Parameter cards, written by FORMAT(20A4). Succeeding records contain the x,y coordinates of the receptor, values for concentration, deposition flux, calibrated concentration, and calibrated surface deposition flux for pollutant-1, followed by the values of these parameters for pollutant-2. These values are written by FORMAT(10F8.2).

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*When the automatic windshift option is selected (NWDOPT > 1), a scenario is divided into four sub-scenarios, each with the same meteorological data except for the wind direction. The latter is shifted automatically by a given number of degrees for each sub-scenario.

NARRAY --- Array maps of concentration and surface deposition flux

At the end of each averaging-period, separate maps are printed for concentration and deposition flux for each pollutant. The values are printed at each receptor at its relative location on the grid to aid in visualization of the distribution of the pollutant.

The value specified for NARRAY determines which maps are printed. If NARRAY=1, separate maps of uncalibrated and calibrated concentrations, and uncalibrated deposition flux are printed (3 maps); if NARRAY=2, maps of uncalibrated concentration and deposition flux only are printed (2 maps); and if NARRAY=3, two maps of only the calibrated values are printed. Each map may require one, two, or four pages of output to display the entire grid, since each page can display values for up to 25 columns and 25 rows of the grid.

NMAX --- Maximum concentration and surface deposition flux

At the end of the last scenario or sub-scenario (if NTOPT=1) or at the end of the averaging period (if NTOPT>1), the receptors which receive the highest concentrations of pollutants-1 and 2, and the values of these concentrations, are listed. A second list gives the surface deposition fluxes at these receptors.

Note : The NCSOPT option can be used only with NTOPT=1; therefore, the output data printed with this option refer to hourly concentrations. When the NMAX option is used with NTOPT=1 and NSCEN > 1, the list of hourly maximum concentration and deposition flux values, and the receptors where they occur, is printed only after the last scenario has been processed.

When the time-averaging is selected (NTOPT=2 or 3), the output for option NPRINT is printed after each scenario, but the output for options NLIST, NTAPE, NARRAY, and NMAX is printed only after all scenarios of the averaging period have been processed. Thus, the concentrations and surface deposition fluxes printed in the output of the latter set of options represent the time-averaged values.

4.4 DISCUSSION OF I/O PARAMETERS

The PEM-2, designed to predict short-term (1 to 24 hr) average ground-level concentrations, assumes that emission rates are constant over the averaging period for NTOPT > 1. This may not be a good assumption for cases where the emissions are strongly time-dependent. For these cases, concentration estimates may be made for each hour with NTOPT = 1, using the appropriate emissions data and the mean meteorological conditions for that hour. Then concentrations for a period longer than an hour can be determined by averaging the hourly concentrations of that period. This can be done externally with minimal programming. The tape output option NTAPE=1 may be used to store the hourly concentration data.

The deposition and sedimentation velocities of the species and the chemical transformation rate are also assumed to be constant over the concentration-averaging period. If it is important to consider the diurnal variations of these parameters, a procedure similar to that described above for emissions can be used in concentration calculations.

The meteorological data input to PEM-2 consist of atmospheric stability class, wind speed, wind direction, temperature, mixing height, and the potential temperature gradient in the elevated stable layer. Each of these hourly data sets is called a scenario. For a given set-up of the receptor grid, the pattern of the impacted receptors downwind of a source depends primarily on the wind direction. For urban-planning or regulatory purposes, it may be necessary to investigate the effects of different wind directions on the calculated concentration patterns in the receptor grid. The PEM-2 has an option which divides each scenario into four sub-scenarios, each consisting of the same hourly meteorological data except for the wind direction. When the user selects this automatic windshift option (i.e., NWDOPT > 1), the wind direction for only the first of the four sub-scenarios is specified by the user. For each succeeding sub-scenario, the wind direction is automatically shifted clockwise by a fixed number of degrees and the concentration calculations are repeated. The magnitude of this shift may be as large as 90° (for NWDOPT = 2), or as small as 5° (for NWDOPT = 7).

The calculated concentrations, C_i, of the species in the PEM-2 are given in $\mu g/m^3$; these are referred to as uncalibrated values, and represent only the contributions of the sources to the concentrations at the receptors. The user may add the background concentrations, or express the calculated concentrations in parts per million or percent allowable, by the formula

$$C_i^* = A_i + B_i \cdot C_i \ , \quad i = 1 \text{ or } 2,$$

where A_i and B_i are the user-specified calibration coefficients (with default values of zero), and C_i^* are the calibrated concentrations of the species. Depending on the value specified for NARRAY, the PEM-2 output may consist of array maps of either uncalibrated values or calibrated values, or both, of concentrations and surface deposition fluxes.

The culpability list output option, NCSOPT, is used for evaluation of control strategies. When this option is in effect, the five point sources which contributed most to the total concentration at each receptor are identified and their percent contributions are printed for each scenario. This option may be used for one or two pollutants, but only when the model calculates hourly concentrations with the time-averaging option NTOPT = 1.

Based on the number of pollutants (NPOL = 1 or 2) and the chemical transformation/decay option parameter (ICT = 0 or 1) specified in the input to the model, the PEM-2 program does one of the following:

1. If NPOL = 1 and ICT = 0 or 1, surface concentrations and deposition fluxes of one gaseous or particulate pollutant, with the given deposition and settling velocities, VD1 and W1 respectively, are calculated. If ICT = 1, then chemical decay of the pollutant is also considered if the decay rate XKT > 0. is given.
2. If NPOL = 2 and ICT = 0, surface concentrations and deposition fluxes of two different and uncoupled gaseous or particulate pollutant species with the given deposition and settling velocities, VD1 and W1 (for species-1) and VD2 and W2 (for species-2) respectively, are calculated. Emission rates for both species may be different. Chemical decay is not considered for either species even if XKT > 0.
3. If NPOL = 2 and ICT = 1, the two gaseous or particulate pollutant species are coupled through a first-order chemical transformation. The surface concentrations and deposition fluxes of both the primary pollutant (species-1 or reactant) as well as the secondary pollutant (species-2 or reaction product) are calculated. The chemical transformation rate (XKT > 0.) should be given. Non-zero direct emissions of the secondary pollutant from the point and/or area sources may also be specified as input for this case.

The specification of the deposition and gravitational settling velocities in the model is discussed in Appendix C.

4.5 EXAMPLE PROBLEMS

Three example problems are described below and the input data and output results of PEM-2 runs for these problems are shown in Appendix E to illustrate the use of the PEM-2 model.

Example 1

This problem deals only with area sources of all types. The first area source is of the same size as one receptor (or calculation) grid square. The second and third area sources are large and each covers several receptor grid squares. The fourth area source, covering one grid square, is imbedded in the third. All area source emissions are assumed to be at 10 m height. The receptor grid has 25 columns and 25 rows with a fine spacing of 1 km. Two chemically-coupled pollutants with a transformation rate of 1 percent per hour, and deposition velocities of VD1=1.0 and VD2=0.1 cm/sec, are calculated. Direct emission rates for pollutant-2 are specified to be one-tenth of the emission rates for pollutant-1. The input meteorology consists of three scenarios, each with the same wind direction but different wind speed and stability class. The output consists of array maps of 3-hour average surface concentrations and deposition fluxes, and a listing of the receptor with the highest average concentration of each pollutant.

Example 2(a)

This example considers two isolated point sources with tall stacks and very hot emissions to illustrate the new schemes in PEM-2 for buoyancy-dominated plume rise and plume penetration above mixing height. The direct emission rate of pollutant-2 is assumed to be 5 percent of the emission rate of pollutant-1. The chemical transformation rate is 10 percent/hour, and the deposition parameters are VD1=2.0, W1=0.0, VD2=0.5, and W2=0.2 cm/sec. The receptor grid has 25 columns and 25 rows, each spaced 2 km apart. Only one scenario is specified with stability class D, wind speed class 2, wind direction sector number 9, and a potential temperature gradient of 0.001 deg C/m above a mixing height of 550 m. The low values of the last two parameters are selected so that the plumes from the two stacks show significant penetration above the mixing height; the calculated plume penetration fractions (see Appendix B), printed by output option NPRINT (which gives the plume rise information), are 0.450 and 0.163 for stacks 1 and 2, respectively. Other output options selected print array maps of surface concentration and deposition flux for each pollutant, and the receptor with the highest concentrations for the hour.

Example 2(b)

The problem described above is repeated here, but with the standard (default) plume rise and penetration schemes in PEM-2; all of the other input-option parameters and data remain the same as given above, in order to facilitate comparison of the surface concentrations calculated by the "old" and "new" methods of accounting for the plume rise and penetration. The maximum effective source heights calculated by the two methods are about the same for stack 1, but the new penetration scheme (Example 2a) estimates that only 55 percent of the plume remains in the mixed layer and contributes to the concentrations, whereas the entire plume remains in the mixed layer in Example 2b. Therefore, for stack 1, the concentrations calculated in Example 2b are nearly twice as large as the corresponding values in Example 2a. For stack 2, the new schemes give a larger effective source height and estimate that only 84 percent of the plume remains within the mixed layer; therefore, the concentrations calculated in Example 2a are again smaller than in Example 2b.

This comparison clearly illustrates the need for the new plume rise equations which account for the differences between unstable and neutral conditions, and the new penetration schemes which consider partial plume penetration while accounting for the stratification in the elevated stable layer. In general, the standard "all or none" criterion predicts more occurences of plume penetration (which results in zero ground-level concentrations) than the new penetration schemes; the Examples given above are clearly designed to show the opposite in order to facilitate comparison.

Example 3

This problem deals with one large ground-level area source and three isolated point sources. The average direct emission rate of pollutant-2 is about 10 percent (or less) of the emission rate of pollutant-1. The chemical transformation rate is 5 percent/hour, and the deposition parameters are VD1=2.0, W1=0.0, VD2=0.2, and W2=0.0 cm/sec. The receptor grid has 25 columns and 25 rows with 1.5 km spacing. Six scenarios, representing moderately stable conditions, low temperatures, and variable wind speeds and directions, are specified. The input option NWPOPT=1 is elected; this requires the use of site-specific values for wind profile exponents and anemometer height given on Card 7. The atmospheric potential temperature gradients for E and F stability classes are specified as 0.015 and 0.030 deg C/m, respectively. The output includes array maps of 6-hour average concentrations and deposition fluxes for each pollutant, and the receptor with the highest concentrations for the averaging period.

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APPENDIX A

POINT SOURCE ALGORITHMS

The algorithms used in PEM-2 to calculate ground-level concentrations of gaseous or particulate pollutants released from an elevated continuous point source are derived by Rao (1982). These algorithms are based on a gradient-transfer model which describes the atmospheric transport, diffusion, dry deposition, sedimentation, and a first-order chemical transformation of pollutants. The analytical solutions of the model are expressed in terms of the empirical Gaussian plume dispersion parameters and extended to various atmospheric stability and mixing conditions. Details of the model and the solutions can be found in that reference. Here we only list the parameterized point source algorithms for the primary (reactant) and the secondary (reaction product) pollutants, denoted by subscripts 1 and 2, respectively.

For convenience, we adopt the following nondimensionalization scheme: All velocities are nondimensionalized by U, the constant mean wind speed. The horizontal downwind distance x and all vertical height quantities are nondimensionalized by $\sqrt{2}\ \sigma_z$; the chemical transformation time scale τ_c is nondimensionalized by $\sqrt{2}\ \sigma_z/U$. The horizontal crosswind distance y is nondimensionalized by $\sqrt{2}\ \sigma_y$. Thus, we define

$$\begin{aligned}
&\hat{V}_{d1} = V_{d1}/U \quad , \quad \hat{V}_{d2} = V_{d2}/U \\
&\hat{W}_1 = W_1/U \quad , \quad \hat{W}_2 = W_2/U \\
&\hat{V}_{11} = \hat{V}_{d1} - \hat{W}_1/2 \quad , \quad \hat{V}_{12} = \hat{V}_{d2} - \hat{W}_2/2 \\
&\hat{V}_{13} = \hat{V}_{11} - (\hat{W}_1 - \hat{W}_2)/2 \\
&\hat{V}_{21} = \hat{V}_{d1} - \hat{W}_1 \quad , \quad \hat{V}_{22} = \hat{V}_{d2} - \hat{W}_2 \\
&\hat{x} = x/\sqrt{2}\,\sigma_z \quad , \quad \hat{z} = z/\sqrt{2}\,\sigma_z \\
&\hat{H} = H/\sqrt{2}\,\sigma_z \quad , \quad \hat{L} = L/\sqrt{2}\,\sigma_z \\
&\hat{\tau}_c = \tau_c\, U/\sqrt{2}\,\sigma_z \quad , \quad \hat{y} = y/\sqrt{2}\,\sigma_z
\end{aligned} \tag{A-1}$$

where

H = effective height of source

L = height of the inversion lid or mixing depth

V_{d1} , V_{d2} = dry deposition velocities of primary and secondary pollutants

W_1 , W_2 = gravitational settling velocities of primary and secondary pollutant particles

x, y, z = horizontal downwind, horizontal crosswind, and vertical coordinates

σ_y , σ_z = Gaussian dispersion parameters in y and z directions

τ_c = characteristic time scale of first-order chemical transformation.

The nondimensional functions g'_{21} and g'_{22} used in Eq. (1) of Section 2.2.1 are now defined as follows:

$$g_1(\hat{x},\hat{y}) = \exp(-\,\hat{y}^2) \tag{A-2}$$

$$g'_{21}(\hat{x},0) = 2\,\exp(-\beta_1^2 - \hat{x}/\hat{\tau}_c) \cdot (1 - \alpha_1) \tag{A-3}$$

where $\alpha_1 = 2\sqrt{\pi}\,\hat{V}_{11}\,\hat{x}\;e^{\xi_1^2}\,\mathrm{erfc}\,\xi_1$

$$\beta_1 = \hat{W}_1\,\hat{x} - \hat{H}$$

$$\xi_1 = \hat{H} + 2\,\hat{V}_{11}\,\hat{x} \tag{A-4}$$

$$g'_{22}(\hat{x},0) = 2\,e^{-\beta_2^2}\Big[\,(Q_2/Q_1 + \gamma)\cdot(1 - \alpha_2)$$

$$-\,\gamma\,\exp(-\,\hat{x}/\hat{\tau}_c)\cdot(1 - \alpha_3)$$

$$-\,\gamma\,2\sqrt{\pi}\,(\hat{V}_{21} - \hat{V}_{22})\,\hat{x}\cdot e^{\hat{H}^2}\cdot F_1(\hat{x},0)\Big] \tag{A-5}$$

where $\alpha_2 = 2\sqrt{\pi}\,\hat{V}_{12}\;\hat{x}\,e^{\xi_2^2}\,\mathrm{erfc}\,\xi_2$

$$\alpha_3 = 2\sqrt{\pi}\,\hat{V}_{13}\;\hat{x}\,e^{\xi_3^2}\,\mathrm{erfc}\,\xi_3$$

$$\beta_2 = \hat{W}_2\,\hat{x} - \hat{H}$$

$$\xi_2 = \hat{H} + 2\,\hat{V}_{12}\,\hat{x}\;,\quad \xi_3 = \hat{H} + 2\,\hat{V}_{13}\,\hat{x} \tag{A-6}$$

and

$$F_1(\hat{x},0) = \frac{1}{\pi} \int_0^1 \frac{1}{\sqrt{t(1-t)}} \exp\left(\frac{-\hat{H}^2}{t} - \frac{\hat{x}t}{\hat{\tau}_c} \right) \cdot$$

$$\left[1 - \sqrt{\pi}\,(\xi_4 - \hat{H}/\sqrt{t})\ e^{\xi_4^2} \operatorname{erfc} \xi_4 \right]$$

$$\left[1 - \sqrt{\pi}\,\xi_5\ e^{\xi_5^2} \operatorname{erfc} \xi_5 \right] dt \qquad \text{(A-7)}$$

where

$$\xi_4 = \hat{H}/\sqrt{t} + 2\,\hat{V}_{13}\ \hat{x}\,\sqrt{t}$$

$$\xi_5 = 2\,\hat{V}_{12}\,\hat{x}\,\sqrt{1-t} \qquad \text{(A-8)}$$

In Eq. (A-5), γ is the ratio of molecular weight of the secondary pollutant to molecular weight of the primary pollutant, and Q_2/Q_1 is the corresponding ratio of emission rates of species. In Eq. (A-7), t is a parameterized dimensionless variable of integration with limits of 0 and 1.

The nondimensional functions g'_{41} and g'_{42} used in Eq. (2) of Section 2.2.1 are defined as follows:

For $\hat{V}_{d1} \neq \hat{W}_1$ or $\hat{V}_{21} \neq 0$,

$$g'_{41}(\hat{x}) = \exp(-\beta_1^2 - \hat{x}/\hat{\tau}_c) \left[(\hat{V}_{11}/\hat{V}_{21})\ e^{\xi_1^2} \operatorname{erfc} \xi_1 \right. \qquad \text{(A-9)}$$

$$\left. - (\hat{W}_1/2\hat{V}_{21})\ e^{\beta_1^2} \operatorname{erfc} \beta_1 \right]$$

where $\xi_1 = 2\,\hat{V}_{11}\,\hat{x}$ and $\beta_1 = \hat{W}_1\,\hat{x}$.

For $\hat{V}_{d1} = \hat{W}_1$ or $\hat{V}_{21} = 0$,

$$g'_{41}(\hat{x}) = \exp(-\xi_1^2 - \hat{x}/\hat{\tau}_c)\left[(1 + 2\,\xi_1^2)\,e^{\xi_1^2}\,\mathrm{erfc}\,\xi_1 - 2\,\xi_1/\sqrt{\pi}\right] \qquad \text{(A-10)}$$

where $\xi_1 = 2\,\hat{V}_{11}\,\hat{x} = \hat{V}_{d1}\hat{x} = \hat{W}_1\,\hat{x}$.

For $\hat{V}_{21} \neq 0$ and $\hat{V}_{22} \neq 0$,

$$\begin{aligned} g'_{42}(\hat{x}) = e^{-\beta_2^2} \Bigg[&(Q_2/Q_1 + \gamma)\left\{(\hat{V}_{12}/\hat{V}_{22})\,e^{\xi_2^2}\,\mathrm{erfc}\,\xi_2 - (\hat{W}_2/2\hat{V}_{22})\,e^{\beta_2^2}\,\mathrm{erfc}\,\beta_2\right\} \\ &- \gamma\,e^{-\hat{x}/\hat{\tau}_c}\left\{(\hat{V}_{13}/\hat{V}_{21})\,e^{\xi_3^2}\,\mathrm{erfc}\,\xi_3 - (\hat{W}_2/2\,\hat{V}_{21})\,e^{\beta_2^2}\,\mathrm{erfc}\,\beta_2\right\} \\ &- \gamma\,4\sqrt{\pi}\,(\hat{V}_{21} - \hat{V}_{22})\,\hat{x}\cdot F_2(\hat{x}) \Bigg] \end{aligned} \qquad \text{(A-11)}$$

where $\xi_2 = 2\,\hat{V}_{12}\,\hat{x}$, $\beta_2 = \hat{W}_2\,\hat{x}$

$$\xi_3 = 2\,\hat{V}_{13}\,\hat{x}\ , \quad \hat{V}_{13} = \hat{V}_{11} - (\hat{W}_1 - \hat{W}_2)/2 \qquad \text{(A-12)}$$

$$F_2(\hat{x}) = \frac{1}{2\pi}\int_o^1 \frac{1}{\sqrt{t}}\ \exp(-\hat{x}t/\hat{\tau}_c)\ \left[\ 1 - \sqrt{\pi}\ \xi_4\ e^{\xi_4^2}\ \mathrm{erfc}\ \xi_4\ \right] \cdot$$

$$\left[(\hat{V}_{12}/\hat{V}_{22})\ \ e^{\xi_5^2}\ \mathrm{erfc}\ \xi_5 - (\hat{W}_2/2\hat{V}_{22})\ e^{\xi_6^2}\ \mathrm{erfc}\ \xi_6\right] dt, \qquad \text{(A-13)}$$

where $\xi_4 = \xi_3\ \sqrt{t}\ ,\ \ \xi_5 = \xi_2\ \sqrt{1-t}\ ,\ \ \xi_6 = \beta_2\ \sqrt{1-t}$ (A-14)

For $\hat{V}_{21} \neq 0$ and $\hat{V}_{22} = 0$,

$$g'_{42}(\hat{x}) = e^{-\xi_2^2}\left[\ (Q_2/Q_1 + \gamma)\left\{\ (1 + 2\ \xi_2^2)\ e^{\xi_2^2}\ \mathrm{erfc}\ \xi_2 - 2\ \xi_2/\sqrt{\pi}\ \right\}\right.$$

$$- \gamma\ e^{-\hat{x}/\hat{\tau}_c}\left\{\ (\hat{V}_{13}/\hat{V}_{21})\ e^{\xi_3^2}\ \mathrm{erfc}\ \xi_3 - (\hat{W}_2/2\hat{V}_{21})\ e^{\xi_2^2}\ \mathrm{erfc}\ \xi_2\ \right\}$$

$$\left. - \gamma\ 4\sqrt{\pi}\ \hat{V}_{21}\ \hat{x} \cdot F_2(\hat{x})\ \right] \qquad \text{(A-15)}$$

where $\xi_2 = 2\ \hat{V}_{12}\ \hat{x} = \hat{V}_{d2}\ \hat{x} = \hat{W}_2\ \hat{x} = \beta_2\ \ ,\ \ \xi_3 = 2\ \hat{V}_{13}\ \hat{x}$

$$F_2(\hat{x}) = \frac{1}{2\pi}\int_o^1 \frac{1}{\sqrt{t}}\ \exp(-\hat{x}t/\hat{\tau}_c)\ \left[\ 1 - \sqrt{\pi}\ \xi_4\ e^{\xi_4^2}\ \mathrm{erfc}\ \xi_4\ \right] \cdot$$

$$\left[\ (1 + 2\ \xi_5^2)\ e^{\xi_5^2}\ \mathrm{erfc}\ \xi_5\ - \ 2\ \xi_5/\sqrt{\pi}\ \right] dt, \qquad \text{(A-16)}$$

with $\xi_4 = \xi_3 \sqrt{t}$, $\xi_5 = \xi_2 \sqrt{1-t}$.

For $\hat{V}_{21} = 0$ and $\hat{V}_{22} \neq 0$,

$$g'_{42}(\hat{x}) = e^{-\xi_3^2} \Bigg[(Q_2/Q_1 + \gamma) \left\{ (\hat{V}_{12}/\hat{V}_{22})\, e^{\xi_2^2} \operatorname{erfc} \xi_2 - (\hat{W}_2/2\hat{V}_{22})\, e^{\xi_3^2} \operatorname{erfc} \xi_3 \right\}$$

$$- \gamma\, e^{-\hat{x}/\hat{\tau}_c} \left\{ (1 + 2\,\xi_3^2)\, e^{\xi_3^2} \operatorname{erfc} \xi_3 - 2\,\xi_3/\sqrt{\pi} \right\}$$

$$+ \gamma\, 4\sqrt{\pi}\, \hat{V}_{22}\, \hat{x} \cdot F_2(\hat{x}) \Bigg] \tag{A-17}$$

where $\xi_2 = 2\,\hat{V}_{12}\,\hat{x}$, $\xi_3 = 2\,\hat{V}_{13}\,\hat{x} = \hat{W}_2\,\hat{x} = \beta_2$,

and $F_2(\hat{x})$ is given by Eq. (A-13).

For $\hat{V}_{21} = 0$ and $\hat{V}_{22} = 0$,

$$g'_{42}(\hat{x}) = \left[Q_2/Q_1 + \gamma\,(1 - e^{-\hat{x}/\hat{\tau}_c}) \right] \cdot$$

$$e^{-\xi_2^2} \left\{ (1 + 2\,\xi_2^2)\, e^{\xi_2^2} \operatorname{erfc} \xi_2 - 2\,\xi_2/\sqrt{\pi} \right\} \tag{A-18}$$

where $\xi_2 = \hat{W}_2\,\hat{x} = \beta_2$.

In Eqs. (A-7), (A-13), and (A-16), t is a parameterized integration variable. The integrand functions in these equations have singularities at the end-points $t=0$ and $t=1$ of the integration domain it t. Because of their complexity, these integrations cannot be carried out analytically; therefore, they should be evaluated by numerical integration to a sufficiently high degree of accuracy.

A computer-library subroutine named D01AJF, developed by the Numerical Algorithms Group (NAG), is utilized in PEM-2 for the numerical integration. This general purpose integrator routine, which is capable of handling the singularities, has been selected because of its accuracy and applicability. It estimates the value of a definite integral of an externally defined function over a finite range to a specified absolute or relative accuracy, using Gauss-Kronrod rules in an adaptive strategy with extrapolation. Further details of this subroutine can be found in Appendix D.

In the limit, when $V_{di} = W_i = 0$ and τ_c and ∞, the algorithms for g'_{21}, g'_{22}, g'_{41}, and g'_{42} (defined above) reduce to the familiar Gaussian-plume diffusion algorithms currently used in EPA air quality models. Thus the new algorithms given in this section may be though of as extensions of the latter to include deposition, sedimentation, and chemical transformation.

It should be noted that the algorithms for g'_{21} and g'_{22} are also used in Eq. (5) of Section 2.3.2 to calculate ground-level concentrations from area sources.

REFERENCE

Rao, K. S., 1982: Plume Concentration Algorithms with Deposition Sedimentation, and Chemical Transformation. EPA-600/3-84-042, U.S. Environmental Protection Agency, Research Triangle Park, NC, 87 pp. [NTIS PB 84-138 742].

APPENDIX B

PLUME RISE EQUATIONS AND PLUME PENETRATION METHODS

The various optional schemes used in PEM-2 for treatment of the stack-plume downwash, plume rise (including criteria for the crossover between momentum and buoyancy), and plume penetration of elevated stable layers are briefly described and the equations listed here. For further information, the user should consult the references cited.

Stack Downwash

PEM-2 provides a default option (NSTDWN=0) to account for the stack-tip downwash of the plume, following Briggs (1973), as follows:

$$\begin{aligned} h_s' &= h_s + 2\,(R - 1.5)\,d \,, && \text{for } R < 1.5 \\ h_s' &= h_s \,, && \text{for } R \geqq 1.5 \end{aligned} \tag{B-1}$$

where $R = V_s/U$ and $h_s' \geqq 0$ is the "reduced" physical stack height. The various symbols are defined below. If the user specifies NSTDWN=1, the downwash correction is not used.

Plume Rise

The plume rise is estimated using Briggs' (1969, 1971) standard equations if the default option NPRISE=0 is used in PEM-2. There are four different situations for plume rise, and the corresponding equations can be written as follows:

1) For a buoyancy-dominated plume in unstable/neutral atmosphere,

$$\Delta h(x) = 1.6\, F_b^{1/3}\, x^{2/3}\, U^{-1} \;, \text{ for } x < x_{max} \qquad \text{(B-2)}$$

and

$$\Delta h = 1.6\, F_b^{1/3}\, x_{max}^{2/3}\, U^{-1} \;, \text{ for } x \geqq x_{max} \qquad \text{(B-3)}$$

where

$$x_{max} = 49\, F_b^{5/8} \;, \text{ for } F_b < 55$$

and

$$x_{max} = 119\, F_b^{2/5} \;, \text{ for } F_b \geqq 55 \qquad \text{(B-4)}$$

Note that by substituting (B-4) in (B-3), the maximum plume rise can also be expressed as

$$\Delta h = 21.425\, F_b^{3/4}\, U^{-1} \;, \text{ for } F_b < 55$$

and

$$\Delta h = 38.71\, F_b^{3/5}\, U^{-1} \;, \text{ for } F_b \geqq 55 \qquad \text{(B-5)}$$

2) For a momentum-dominated plume in unstable/neutral atmosphere,

$$\Delta h(x) = 1.89\, [R^2 d/(R+3)]^{2/3}\, x^{1/3} \;, \text{ for } x < x_{max} \qquad \text{(B-6)}$$

and $$\Delta h = 3\ R\ d\ ,\ \text{for}\ x \geqq x_{max} \qquad \text{(B-7)}$$

where $$x_{max} = 4d(R+3)^2/R \quad \text{and} \quad R = V_s/U \qquad \text{(B-8)}$$

3) For a buoyancy-dominated plume in stable atmosphere,

$$\Delta h(x) = 1.6\ F_b^{1/3}\ x^{2/3}\ U^{-1}\ ,\ \text{for}\ x < x_{max} \qquad \text{(B-9)}$$

and $$\Delta h = 2.6\ (F_b/U\ s)^{1/3}\ ,\ \text{for}\ x \geqq x_{max} \qquad \text{(B-10)}$$

where $$x_{max} = 2.0715\ U\ s^{-1/2} \qquad \text{(B-11)}$$

and $$s = (g/T_a)\ \partial\theta_a/\partial z \qquad \text{(B-12)}$$

In (B-12), $\partial\theta_a/\partial z > 0$ is the vertical gradient of potential temperature in stable atmosphere. Its value may be specified by the user; otherwise, PEM-2 uses the default values of 0.02 and 0.035°K/m for E and F stability classes, respectively.

4) For a momentum-dominated plume in stable atmosphere,

$$\Delta h = 1.5\ (F_m/U)^{1/3}\ s^{-1/6} \qquad \text{(B-13)}$$

and $$x_{max} = 0$$

For this case, there is no expression given for $\Delta h(x)$ since (B-13) is assumed to apply for all values of x. The smaller of the two Δh values calculated from (B-7) and (B-13) is taken as the final plume rise in this case.

After calculating the maximum plume rise from one of the equations given above, the effective source height can be obtained from

$$H = h_s' + \Delta h \qquad \text{(B-14)}$$

The variables used in the equations listed above are defined here:

$F_b = 0.25\ (g/T_s)\ V_s\ d^2\ \Delta T$ (B-15)

= plume buoyancy flux at stack exit, m^4/s^3

$F_m = 0.25\ (T_a/T_s)\ V_s^2\ d^2$ (B-16)

= plume momentum flux at stack exit, m^4/s^2

d = inside diameter of stack-tip, m

g = acceleration due to gravity, 9.8 m/s^2

h_s = physical stack height, m

h_s' = "reduced" physical stack height for downwash cases, m

H = effective source height, m

s = stability parameter, s^{-2}

T_a = atmospheric temperature, °K

T_s = plume temperature at stack exit, °K

U = mean wind speed at physical stack height, m/s

V_s = plume velocity at stack exit, m/s

x = downwind distance from stack, m

x_{max} = downwind distance at maximum plume rise, m

$\Delta h(x)$ = distance-dependent plume rise, m

Δh = maximum or final plume rise, m

$\Delta T = T_s - T_a$, plume temperature excess, °K

Crossover Between Momentum and Buoyancy

In order to properly use the plume rise equations given above, one should know whether the plume is dominated by momentum or buoyancy. This determination is generally based on the crossover temperature difference, $(\Delta T)_c$. Analytic expressions for $(\Delta T)_c$ can be derived, for given atmospheric conditions, by setting the maximum plume rise equation for the buoyancy-dominated plume equal to the corresponding equation for the momentum-dominated plume.

For unstable/neutral atmosphere, equating (B-5) to (B-7), we obtain the expressions

$$(\Delta T)_c = .02964\ T_s\ V_s^{1/3}\ d^{-2/3},\ \text{for } F_b < 55 \qquad \text{(B-17)}$$

and

$$(\Delta T)_c = .00575\ T_s\ V_s^{2/3}\ d^{-1/3},\ \text{for } F_b \geqq 55 \qquad \text{(B-18)}$$

For stable atmosphere, equating (B-10) to (B-13), we obtain the expression

$$(\Delta T)_c = .01957\ T_a\ V_s\ s^{1/2} \qquad \text{(B-19)}$$

For any given atmospheric stability, the plume is assumed to be buoyancy-dominated if $T_s > T_a$ and $\Delta T = T_s - T_a$ exceeds the crossover temperature difference $(\Delta T)_c$ calculated from the appropriate expression given above. If $T_s \leqq T_a$ or if $\Delta T \leqq (\Delta T)_c$, the plume is assumed to be momentum-dominated.

From (B-15), (B-17) and (B-18), the crossover criteria for unstable/neutral atmosphere may also be expressed in terms of the crossover plume-buoyancy flux, $(F_b)_c$, as follows:

$$(F_b)_c = .0727\ (V_s d)^{4/3}\ ,\ \text{for } F_b < 55 \qquad \text{(B-20)}$$

$$(F_b)_c = .0141\ (V_s d)^{5/3}\ ,\ \text{for } F_b \geq 55 \qquad \text{(B-21)}$$

If $F_b > 0$ and $F_b > (F_b)_c$, then the plume is buoyancy-dominated; otherwise, it is momentum-dominated.

Similarly, from (B-12) and (B-19), the crossover criteria for stable conditions can be expressed in terms of the crossover plume velocity, $(V_s)_c$, as follows:

$$(V_s)_c = 115.28\ \Delta T/T_a^{1/2} \quad \text{for E-stability}$$

(B-22)

$$(V_s)_c = 87.14\ \Delta T/T_a^{1/2} \quad \text{for F-stability}$$

The default values of 0.02 and 0.035°K/m for E and F stability classes, respectively, are assumed for $\partial\theta_a/\partial z$ in the above expressions. If the values specified by the user are significantly different, then the following general expression may be utilized:

$$(V_s)_c = 16.30\ \Delta T/(T_a\ \partial\theta_a/\partial z)^{1/2} \qquad \text{(B-23)}$$

If $(V_s)_c > 0$ and $V_s < (V_s)_c$, then the plume is buoyancy-dominated; otherwise, it is momentum-dominated.

New Plume Rise Equations

For a buoyancy-dominated plume, the maximum plume rise given by (B-5) compromises substantial differences between unstable (convective turbulence) and neutral (mechanical turbulence) atmospheric conditions. The inverse dependence of final plume rise on wind speed in (B-5) is rather simplistic, and the equations may seriously overpredict Δh for low-level sources at high wind speeds.

PEM-2 provides an option (NPRISE=1) to use Briggs' (1975, 1984) new equations to estimate the maximum rise of a buoyancy-dominated plume in unstable/neutral atmosphere. The new plume-rise equations show a weaker dependence of Δh on U in unstable conditions and a considerably stronger dependence on U in neutral conditions. These equations, which contain the minimum essential physics with the maximum allowable simplifications, can be written as follows:

For unstable atmosphere,

$$\Delta h = 30\ (F_b/U)^{3/5}\ , \text{ for } x \geqq x_{max} \tag{B-24}$$

where

$$x_{max} = 81.2\ F_b^{2/5}\ U^{3/5} \tag{B-25}$$

For neutral atmosphere,

$$\Delta h = 24\ (F_b/U^3)^{3/5}\ (h_s' + 200\ F_b/U^3)^{2/5}\ , \text{ for } x \geqq x_{max} \tag{B-26}$$

where

$$x_{max} = 58.1\ (F_b/U^3)^{2/5}\ (h_s' + 200\ F_b/U^3)^{3/5} \tag{B-27}$$

In PEM-2, for unstable/neutral conditions, Δh is evaluated from both (B-24) and (B-26), and the lower of these two values is selected as the maximum buoyancy rise of the plume. Generally, (B-24) gives the lower Δh value for low wind speeds, and (B-26) gives the lower value for high wind speeds. The maximum buoyancy rise thus determined is then compared with the maximum momentum rise of the plume evaluated from (B-7), and the higher of these two values is selected as the maximum plume rise. The distance to the maximum plume rise, x_{max}, is then obtained from one of the equations (B-8), (B-25), and (B-27) that is appropriate for the selected final plume rise. For $x < x_{max}$, the distance-dependent plume rise is determined from (B-2), as before. This procedure was suggested by Turner (1985).

Plume Penetration of Elevated Stable Layer

The daytime turbulent mixed layer with a near-adiabatic lapse rate above the ground is frequently bounded by a thick layer of stably-stratified air aloft. This situation also occurs in the marine inversion layer in some coastal areas. The elevated stable layer then effectively limits vertical dispersion to the mixed layer of depth L. A buoyant plume rising into a convectively or mechanically mixed layer may partially or completely penetrate the capping stable layer, depending on the stratification strength and elevation of the latter with respect to the plume.

The default penetration-option (NINPEN=0) in PEM-2 does not consider partial penetration of the elevated stable layer. If the maximum effective source height, $H = h_s' + \Delta h$, exceeds the mixing depth L, then the pollutants are assumed to be emitted into the stable layer aloft; these pollutants will not be brought to the ground and, therefore, the source is ignored. If $H \leq L$, then the plume is assumed to be trapped within the mixed layer with no ability to penetrate the stable layer aloft. This treatment, which assumes either complete penetration of the elevated stable layer or no penetration at all, is similar to that used in EPA air quality models such as CRSTER.

PEM-2 provides an option (NINPEN=1) to use new penetration schemes that allow consideration of the strength of stratification of the elevated stable layer in estimating the extent of its penetration by a buoyancy-dominated plume in unstable/neutral atmosphere. These schemes, based on the work of Briggs (1975, 1984), Weil and Brower (1982), Turner (1985), and others, are briefly described below.

For a buoyant bent-over plume, the penetration criteria are based on the heights of the upper and lower edges of the plume at final rise, relative to the stable layer height, z_i', above the stack:

$$z_i' = L - h_s \tag{B-28}$$

Based on field observations, Briggs approximated the heights (above the stack) of the upper and lower edges of the bent-over plume by 1.5 Δh and 0.5 Δh, respectively, where Δh is the final rise of the plume. Penetration commences only when the upper edge of the plume is at the top of the mixed layer, i.e., $1.5\ \Delta h = z_i'$ or $\Delta h = (2/3)\ z_i'$. Therefore, the minimum effective plume centerline height necessary to consider penetration is given by

$$H_{pen} = h_s + (2/3)\ z_i' \tag{B-29}$$

where H_{pen} is referred to, hence, as the penetration height. If the effective source height, H, estimated from the standard or new plume-rise formulas given above, is less than H_{pen}, then no penetration occurs. If $H \geqq H_{pen}$, then the fraction of the plume that penetrates the elevated stable layer is computed as given below.

Following Briggs, we define the plume penetration fraction, P, as the ratio of the depth of the plume above the elevated stable layer to the total plume depth:

$$P = (1.5\ \Delta h - z_i')/(1.5\ \Delta h - 0.5\ \Delta h) = 1.5 - z_i'/\Delta h \qquad \text{(B-30)}$$

As a simple and conservative approach to estimate the final plume rise, Briggs assumed that the mixed layer is stably-stratified with the same atmospheric potential temperature gradient, $\partial\theta_{ai}/\partial z$, as that in the elevated stable layer. Thus Δh in (B-30) is estimated from an expression similar to (B-10) for a buoyancy-dominated plume in stable atmosphere:

$$\Delta h = 2.6(F_b/U\ s_i)^{1/3} \qquad \text{(B-31)}$$

where

$$s_i = (g/T_a)\ \partial\theta_{ai}/\partial z \qquad \text{(B-32)}$$

The value of the atmospheric potential temperature gradient in the elevated stable layer is specified by the user in PEM-2; if it is not specified, a default value of 0.01°C/m (corresponding to an isothermal atmosphere) will be assumed by the model. This approach is conservative since the plume rise thus estimated will be much lower than that computed using a near-adiabatic lapse rate which is appropriate for the mixed layer.

The plume penetration fraction P is calculated from (B-30) and (B-31) such that $0 \leq P \leq 1$. No penetration (P=0) is assumed to occur when the plume upper edge is at or below the top of the mixed layer, i.e., $\Delta h \leq (2/3)z_i'$. Complete penetration (P=1) occurs when the lower edge of the plume is at or above the top of the mixed layer, i.e., $\Delta h \geq 2z_i'$. Partial penetration $(0 < P < 1)$ occurs for $0.5\ \Delta h < z_i' < 1.5\ \Delta h$.

In PEM-2, we assume that only the fraction (1-P) of the plume material remaining within the mixed layer contributes to the ground-level concentrations (GLC); essentially, the fraction P of the plume material is lost. The effective source strength, Q_{ek}, is then given by

$$Q_{ek} = (1-P)\, Q_k \ , \quad k = 1,2 \tag{B-33}$$

where Q_k is the emission rate of species-k from the stack. In the concentration algorithms, the effective source height H represents only the height of the centerline of the plume, and not the heights of its upper and lower edges, when the plume is within the mixed layer. For partial penetration cases, therefore, a new effective source height (H_e) should be determined for the fraction of the plume remaining within the mixed layer. First, we consider the two limiting cases, $P \rightarrow 0$ and $P \rightarrow 1$. For $P \rightarrow 0$, H_e is obviously given by H_{pen}, the penetration height defined in (B-29). As $P \rightarrow 1$, the new effective source height should approach L, or $H_e \rightarrow h_s + z_i'$ from (B-28), since the small fractional plume of thickness $(1-P)\Delta h$ that is left at the top of the mixed layer vanishes in the limit $P \rightarrow 1$.

Now, from simple geometric considerations, a general expression for H_e valid for any value of P ($0 \leq P \leq 1$) can be written as

$$H_e = h_s + [z_i' - 0.5\ (1-P)\Delta h]$$

Substituting $\Delta h = z_i'/(1.5-P)$ from (B-30) in the above, we obtain

$$H_e = h_s + [(1-0.5\ P)/(1.5-P)]z_i' \tag{B-34}$$

This equation for H_e is consistent with the definition of P, and also satisfies the limiting behavior, for P=0 and P=1, discussed above. The elevations (above the stack) of the upper and lower edges of the plume material whose centerline is given by (B-34) are z_i' and $z_i'/(3-2P)$, respectively. The solid lines in Figure (B-1) show the variations of normalized elevations of the centerline and edges of this plume as functions of P.

Equation (B-34) for H_e differs from that given by Weil and Brower (1982), who interpolated linearly between the limiting values of H_e at P=0 and P=1, as follows:

$$H_e = h_s + [(2+P)/3]z_i' \qquad \text{(B-35)}$$

The elevations of the upper and lower edges of the plume whose centerline is given by (B-35) are z_i' and $(1+2P)z_i'/3$, respectively. Figure (B-1) shows the centerline and lower edge of this plume in broken lines. It is clear that, though both (B-34) and (B-35) give the same values for H_e at P=0 and P=1, the linear model consistently overpredicts the effective source height of the fractional plume left in the mixed layer for $0 < P < 1$. At P=0.5, for example, (B-35) overpredicts H_e by about 11 percent, and the elevation of the lower edge is overestimated by about 33 percent.

For $0 \leqq P < 1$, the distance downwind from the stack to the location where the new effective source height H_e occurs can be obtained by equating the plume rise from (B-34) to the distance-dependent plume rise given by (B-2) and solving for x:

$$x_{max} = [(1-0.5P)z_i' \, U / 1.6(1.5-P)]^{3/2} \, F_b^{-1/2} \qquad \text{(B-36)}$$

For $x < x_{max}$, the plume rise is predicted from (B-2); for $x \geqq x_{max}$, H_e is given by (B-34).

The various formulas for computing the effective source height and effective source strength can be summarized as follows:

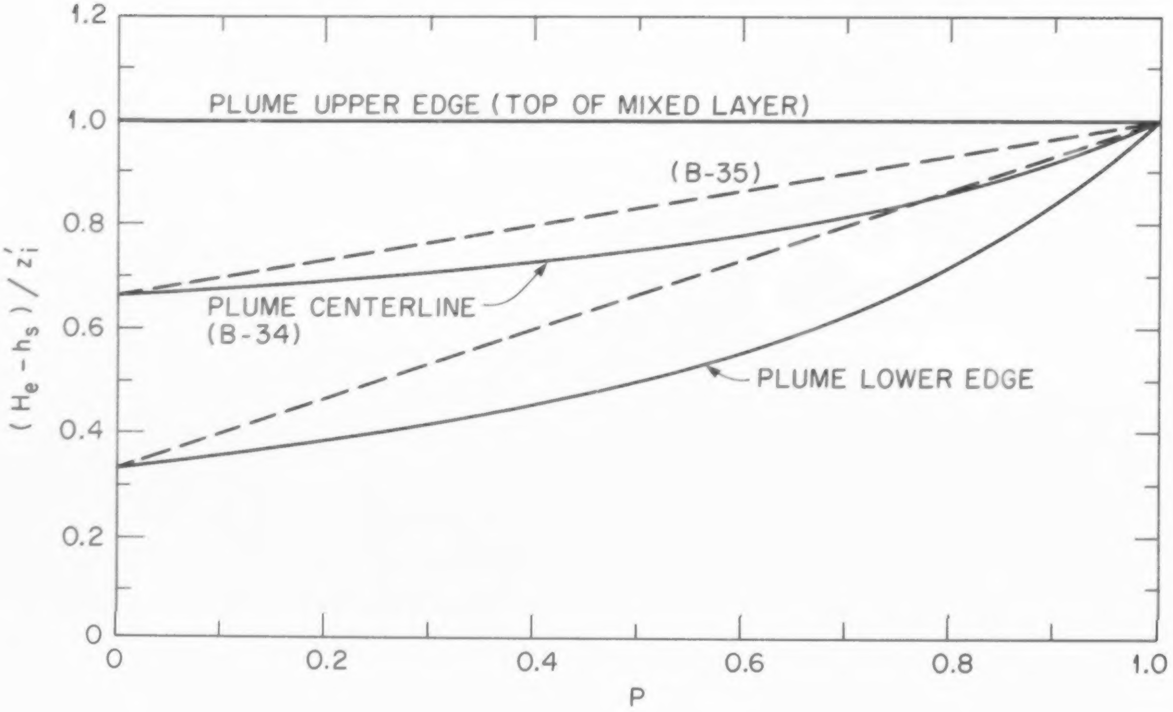

Figure (B-1). Variation of the elevation (above the stack) of the fractional plume left within the mixed layer as a function of the plume penetration fraction. Solid lines show the plume centerline given by Eq. (B-34), and upper and lower edges of the plume for the partial penetration model used in PEM-2. Broken lines show the corresponding plume centerline given by Eq. (B-35), and the lower edge from the linear interpolation model of Weil and Brower (1982). The plume upper edge is the same in both models.

(a) For $H < H_{pen}$, the plume does not penetrate the elevated stable layer, and penetration need not be considered.

$$H_e = H \qquad Q_{ek} = Q_k, \quad k = 1,2 \tag{B-37}$$

(b) For $H \geqq H_{pen}$, the plume penetration fraction P should be computed from (B-30) and (B-31). Then, depending on the value of P, one of the following applies:

(i) For P=1, the entire plume penetrates the elevated stable layer, and the source is ignored since it does not contribute to the GLC.

$$H_e \geqq L \qquad Q_{ek} = 0 \tag{B-38}$$

(ii) For P=0, the entire plume remains within the mixed layer and contributes to the GLC.

$$H_e = H_{pen} \qquad Q_{ek} = Q_k \tag{B-39}$$

(iii) For 0 < P < 1, the plume partially penetrates the elevated stable layer; only the fraction (1-P) of the plume material left in the mixed layer contributes to the GLC.

$$H_e = h_s + [(1-0.5P)/(1.5-P)]z_i' \qquad Q_{ek} = (1-P)\,Q_k \tag{B-40}$$

For cases (ii) and (iii), the downwind distance x_{max} to the effective source height is estimated from (B-36).

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Briggs, G. A., 1969: Plume Rise. AEC Critical Review Series. Available as TID-25075 from NTIS, Springfield, VA, 81 pp.

_________, 1971: Some recent analyses of plume rise observations. Proc. of 2nd Int. Clean Air Congress, H. M. Englund and W. T. Beery, eds. Academic Press, New York, 1029-1032.

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Turner, D. B., 1985: Proposed pragmatic methods for estimating plume rise and plume penetration through atmospheric layers. Atmos. Environ. 19, 1215-1218.

Weil, J. C., and R. B. Brower, 1982: The Maryland PPSP Dispersion Model for Tall Stacks. Report PPSP-MP-36, Environ. Center, Martin Marietta Corp., Baltimore, MD.

APPENDIX C

SURFACE DEPOSITION FLUXES, AND DEPOSITION AND SETTLING VELOCITIES

C.1 SURFACE DEPOSITION FLUXES

The surface deposition fluxes of the primary and the secondary pollutants at ground level receptors are calculated directly as

$$D_1(\hat{x},\hat{y}) = V_{d1} \cdot C_1(\hat{x},\hat{y},0) \qquad \text{(C-1)}$$

$$D_2(\hat{x},\hat{y}) = V_{d2} \cdot C_2(\hat{x},\hat{y},0) \qquad \text{(C-2)}$$

D_i gives the amount of pollutant i deposited per unit time per unit surface area, and is usually calculated in the short term as $\mu g/m^2$-hr or kg/km^2-hr, while seasonal estimates are expressed as kg/km^2-month. The estimation of the monthly or yearly surface deposition fluxes at a given downwind distance x from the source in a given wind-directional sector requires the knowledge of the fraction of the time that a mean wind of a given magnitude blows in that direction in a month or a year, respectively. To obtain D_i in kg/km^2-hr when V_{di} is given in cm/s and C_i in $\mu g/m^3$, the right-hand side of the equations should be multiplied by 0.036. To obtain D_i in $\mu g/m^2$-hr when V_{di} is given in cm/s and C_i in $\mu g/m^3$, the corresponding multiplication factor is 36. For D_i calculations, the ground-level receptor is generally defined as any receptor which is not higher than 1 meter above the local ground-level elevation.

PEM-2 calculates the surface deposition fluxes of one or two pollutants. These values are printed in a map or list form, as specified by the user, in the same way the program prints the concentrations. The flux units are generally μg/m^2-hr; however, if these values are too large to be clearly printed in a map format, the program automatically converts them into kg/km^2-hr before printing.

C.2 DEPOSITION AND SETTLING VELOCITIES

The values of the settling and deposition velocities primarily depend on the particle diameter d. (i) In the trivial case of $W = V_d = 0$, settling and deposition effects are negligible. (ii) For very small particles ($d < 0.1$ μm), gravitational settling can be neglected, and dry deposition occurs primarily due to nongravitational effects. In this case, $W = 0$ but $V_d > 0$. (iii) For small to medium-sized particles ($d = 0.1 \sim 50$μm), $0 < W < V_d$; deposition is enhanced here beyond that due to gravitational settling, primarily because of increased turbulent transfer resulting from surface roughness. (iv) For larger particles ($d > 50$ μm), it is generally assumed that $V_d = W > 0$, since gravitational settling is the dominant deposition mechanism. (v) When $W > V_d > 0$, turbulent re-entrainment of the deposited particles from the surface back into the atmosphere is implied, as in a dust storm, for example. Model parameters such as those given above for cases (i) to (iv) are widely used in the atmospheric dispersion and deposition of particulate material. The deposition of gases is a special case of the particulate problem with $W = 0$; this is similar to case (ii). Thus, one has to carefully select the values of W and V_d for use in the models. A more complete discussion of these model parameters is given by Rao (1982).

REFERENCE

Rao, K. S., 1982: Plume Concentration Algorithms with Deposition, Sedimentation, and Chemical Transformation. EPA-600/3-84-042, U.S. Environmental Protection Agency, Research Triangle Park, NC, 87 pp. [NTIS PB 84-138 742].

APPENDIX D

D01AJF – NAG FORTRAN Library Routine Document

NOTE: before using this routine, please read the appropriate implementation document to check the interpretation of bold *italicised* terms and other implementation-dependent details. The routine name may be precision-dependent.

1. Purpose

D01AJF is a general-purpose integrator which calculates an approximation to the integral of a function F(x) over a finite interval (A,B):

$$I = \int_A^B F(x)\,dx.$$

2. Specification

```
      SUBROUTINE D01AJF (F, A, B, EPSABS, EPSREL, RESULT, ABSERR,
     1    W, LW, IW, LIW, IFAIL)
C      INTEGER LW, IW(LIW), LIW, IFAIL
C      real F, A, B, EPSABS, EPSREL, RESULT, ABSERR, W(LW)
C      EXTERNAL F
```

---

3. Description

D01AJF is based upon the QUADPACK [3] routine DQAGS. It is an adaptive routine, using the Gauss 10-point and Kronrod 21-point rules. The algorithm, described in [1], incorporates a global acceptance criterion (as defined by Malcolm and Simpson [2]) together with the ϵ-algorithm [4] to perform extrapolation. The local error estimation is described in [3].

The routine is suitable as a general purpose integrator, and can be used when the integrand has singularities, especially when these are of algebraic or logarithmic type.

4. References

[1] DE DONCKER, E.
An Adaptive Extrapolation Algorithm for Automatic Integration.
Signum Newsletter 13, No. 2, pp. 12–18, 1978.

[2] MALCOLM, M.A. and SIMPSON, R.B.
Local versus Global Strategies for Adaptive Quadrature.
A.C.M. Trans. Math. Software 1, pp. 129–146, 1976.

[3] PIESSENS, R., DE DONCKER, E., ÜBERHUBER, C. and KAHANER, D.
'QUADPACK', A Quadrature Subroutine Package.
To be published, 1980.

[4] WYNN, P.
On a Device for Computing the $e_m(S_n)$ Transformation.
M.T.A.C, 10, pp. 91–96, 1956.

5. Parameters

F – ***real*** FUNCTION, supplied by the user.

F must return the value of the integrand at a given point.
Its specification is:

real FUNCTION F(X)
real X

X – ***real***.

On entry, X specifies the point at which the integrand value is required by D01AJF. X must not be reset by F.

F must be declared as EXTERNAL in the (sub)program from which D01AJF is called.

A – ***real***.

On entry, A must specify the lower limit of integration.

Unchanged on exit.

B – ***real***.

On entry, B must specify the upper limit of integration.

Unchanged on exit.

EPSABS – ***real***.

On entry, EPSABS must specify the absolute accuracy required. If EPSABS is negative, the absolute value is used. See Section 10.

Unchanged on exit.

EPSREL – *real*.

On entry, EPSREL must specify the relative accuracy required. If EPSREL is negative, the absolute value is used. See Section 10.

Unchanged on exit.

RESULT – *real*.

On exit, RESULT contains the approximation to the integral *I*.

ABSERR – *real*.

On exit, ABSERR contains an estimate of the modulus of the absolute error, which should be an upper bound for $|I - \text{RESULT}|$.

W – *real* array of DIMENSION (LW).

Used as workspace.

LW – INTEGER.

On entry, LW must specify the dimension of W as declared in the calling (sub)program. LW/4 is an upper bound for the number of subintervals into which the interval of integration is divided. A value in the range 800 to 2000 is adequate for most problems. The more difficult the integrand, the larger LW should be. Trivially $\text{LW} \geq 4$. See IW below.

LW is unchanged on exit.

IW – INTEGER array of DIMENSION (LIW).

Used as workspace.

On exit, IW(1) contains the amount of *real* workspace actually used (the smallest possible value of LW).

LIW – INTEGER.

On entry, LIW must specify the dimension of IW, as declared in the calling (sub)program. $\text{LIW} \geq \text{LW}/8 + 2$.

Unchanged on exit.

IFAIL – INTEGER.

Before entry, IFAIL must be assigned a value. For users not familiar with this parameter (described in Chapter P01) the recommended value is 0.

Unless the routine detects an error (see next section), IFAIL contains 0 on exit.

6. Error Indicators and Warnings

Errors detected by the routine:–

IFAIL = 1

The maximum number of subdivisions allowed with the given workspace has been reached without the accuracy requirements being achieved. Look at the integrand in order to determine the integration difficulties. If the position of a local difficulty within the interval can be determined (e.g. a singularity of the integrand or its derivative, a peak, a discontinuity...) one will probably gain from splitting up the interval at this point and calling the integrator on the subranges. If necessary, another integrator which is designed for handling the type of difficulty involved, must be used. Alternatively consider relaxing the accuracy requirements specified by EPSABS and EPSREL, or increasing the amount of workspace.

IFAIL = 2

Roundoff error prevents the requested tolerance from being achieved. The error may be under-estimated. Consider requesting less accuracy.

IFAIL = 3

Extremely bad local integrand behaviour causes a very strong subdivision around one (or more) points of the interval. The same advice applies as in the case of IFAIL = 1.

IFAIL = 4

The requested tolerance cannot be achieved, because the extrapolation does not increase the accuracy satisfactorily; the returned result is the best which can be obtained. The same advice applies as in the case of IFAIL = 1.

IFAIL = 5

The integral is probably divergent, or slowly convergent. It must be noted that divergence can also occur with any non-zero value of IFAIL.

IFAIL = 6

On entry, $\text{LW} < 4$, or $\text{LIW} < \text{LW}/8 + 2$.

7. Auxiliary Routines

This routine calls NAG Library routines D01AJV, D01AJX, D01AJY, D01AJZ, P01AAF, X02AAF, X02ABF and X02ACF.

8. Timing

This depends on the integrand and the accuracy required.

9. Storage

The storage required by internally declared arrays is 107 *real* elements.

10. Accuracy

The routine cannot guarantee, but in practice usually achieves, the following accuracy:

$|I - \text{RESULT}| \leq tol$

where

$$tol = \max\{|\text{EPSABS}|, |\text{EPSREL}| \times |I|\}$$

and EPSABS and EPSREL are user-specified absolute and relative error tolerance. Moreover it returns the quantity ABSERR which, in normal circumstances, satisfies $|I - \text{RESULT}| \leq \text{ABSERR} \leq tol$.

11. Further Comments

Labelled COMMON block AD01AJ is used by this routine and must therefore be avoided by the user.

12. Keywords

Quadrature, Extrapolation, Globally Adaptive, Singularities.

---

13. Example

To compute $$\int_0^{2\pi} \frac{x.\sin(30x)}{\sqrt{(1-(\frac{x}{2\pi})^2)}}\,dx$$

WARNING: This single precision example program may require amendment for certain implementations. The results produced may not be the same. If in doubt, please seek further advice (see Essential Introduction to the Library Manual).

13.1. Program Text

```
C     D01AJF EXAMPLE PROGRAM TEXT
C     MARK 8 RELEASE. NAG COPYRIGHT 1979.
C     .. SCALARS IN COMMON ..
      REAL PI
      INTEGER KOUNT
C     ..
C     .. LOCAL SCALARS ..
      REAL A, ABSERR, B, EPSABS, EPSREL, EX, EXACT, RESULT
      INTEGER IFAIL, NOUT
C     .. LOCAL ARRAYS ..
      REAL W(800)
      INTEGER IW(102)
C     .. FUNCTION REFERENCES ..
      REAL X01AAF
C     .. SUBROUTINE REFERENCES ..
C     D01AJF
C     ..
      EXTERNAL FST
      COMMON /TELNUM/ PI, KOUNT
      DATA EXACT /-0.2543259615893530E+01/
      DATA NOUT /6/
      WRITE (NOUT,99999)
      PI = X01AAF(PI)
      EPSABS = 0.E0
      EPSREL = 1.E-04
      A = 0.E0
      B = 2.E0*PI
      KOUNT = 0
      IFAIL = 1
      CALL D01AJF(FST, A, B, EPSABS, EPSREL, RESULT, ABSERR, W,
     * 800, IW, 102, IFAIL)
      WRITE (NOUT,99998) A, B, EPSABS, EPSREL
      WRITE (NOUT,99997) RESULT, ABSERR, KOUNT, IW(1), IFAIL
      EX = ABS(EXACT-RESULT)
      WRITE (NOUT,99996) EX
      STOP
99999 FORMAT (4(1X/), 31H D01AJF EXAMPLE PROGRAM RESULTS/1X)
99998 FORMAT (1H , 2X, 1HA, 6X, 31H- LOWER LIMIT OF INTEGRATION
     * F10.4/1H , 2X, 1HB, 6X, 31H- UPPER LIMIT OF INTEGRATION = ,
     * F10.4/1H , 2X, 39HEPSABS - ABSOLUTE ACCURACY REQUESTED = ,
     * E9.2/1H , 2X, 39HEPSREL - RELATIVE ACCURACY REQUESTED = ,
     * E9.2/)
99997 FORMAT (1H , 2X, 41HRESULT - APPROXIMATION TO THE INTEGRAL = ,
     * E14.5/1H , 2X, 42HABSERR - ESTIMATE OF THE ABSOLUTE ERROR = ,
     * E10.3/1H , 2X, 42HKOUNT  - NUMBER OF FUNCTION EVALUATIONS = ,
     * I4/1H , 2X, 43HIW(1)  - ELEMENTS OF REAL WORKSPACE USED = ,
     * I4/1H , 2X, 22HIFAIL  - ERROR FLAG = , I4/)
99996 FORMAT (1H , 7X, 27H  - EXACT ABSOLUTE ERROR = , E10.3)
      END
      REAL FUNCTION FST(X)
C     . SCALAR ARGUMENTS .
      REAL X
C     .
C     . SCALARS IN COMMON .
      REAL PI
      INTEGER KOUNT
C     .
C     . FUNCTION REFERENCES ..
      REAL SIN, SQRT
C     .
      COMMON /TELNUM/ PI, KOUNT
      KOUNT = KOUNT + 1
      FST = X*SIN(30.E0*X)/SQRT(1.E0-X**2/(4.E0*PI**2))
      RETURN
      END
C      D01AJF EXAMPLE PROGRAM TEXT
C      MARK 8 RELEASE. NAG COPYRIGHT 1979.
```

13.2. Program Data

None.

13.3. Program Results

```
 D01AJF EXAMPLE PROGRAM RESULTS

  A       - LOWER LIMIT OF INTEGRATION =       0.0000
  B       - UPPER LIMIT OF INTEGRATION =      6.2832
  EPSABS - ABSOLUTE ACCURACY REQUESTED =  0.00E 00
  EPSREL - RELATIVE ACCURACY REQUESTED =  0.10E-03

  RESULT - APPROXIMATION TO THE INTEGRAL =   -0.25433E 01
  ABSERR - ESTIMATE OF THE ABSOLUTE ERROR =  0.125E-04
  KOUNT  - NUMBER OF FUNCTION EVALUATIONS =  777
  IW(1)  - ELEMENTS OF REAL WORKSPACE USED =   76
  IFAIL  - ERROR FLAG =    0

         - EXACT ABSOLUTE ERROR =  0.893E-05
```

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APPENDIX E

INPUT AND OUTPUT LISTINGS OF EXAMPLE PROBLEMS

The input data and output listings for the PEM-2 example problems described in Section 4.5 are shown in the tables of this Appendix as follows:

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E-4 Output listing for Example Problem 2(a) 107

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E-6 Output listing for Example Problem 2(b) 121

E-7 Input data for Example Problem 3 134

E-8 Output listing for Example Problem 3 135

TABLE E-1

INPUT DATA FOR EXAMPLE PROBLEM 1

CARD IMAGES

```
CONTROL CARDS
1  TITLE    PEM-2 EXAMPLE 1: MULTIPLE AREA SOURCES, 2 SPECIES, 3-HR AVG CONC & DEP FLUX
2  OPTIONS    3   0   0   0   3   0   2   0   0   1   1   1   1   1   0   1   1   0
3  GRID            0.          0.        25        25         1.        0.        0.
4  POLLUTANTS  2    1          1.        0.        0.1        0.        1.0       1.5
5  SCALING         10.         1.        1.        0.         0.        0.        0.
6  LABELS  SO2                                      SULFATE
SCENARIO CARDS

                4   4   11       4.      225.        5.     550.      0.
                5   4   11       3.      225.        5.     500.      0.
                6   4   11       2.      225.        5.     500.      0.
AREA SOURCE CARDS
                   1.5     10.5    1000.       10.      1.
                   3.5      3.5    4000.       90.      9.
                   9.5       .5    2000.       20.      2.
                   9.5       .5    1000.        5.       .5
              (A BLANK CARD TO SIGNAL END OF AREA SOURCE INVENTORY)
```

TABLE E-2

OUTPUT LISTING FOR EXAMPLE PROBLEM 1

PEM-2 (VERSION 84130)

POLLUTION EPISODIC MODEL

INCLUDING

DEPOSITION, SEDIMENTATION, AND CHEMICAL TRANSFORMATION

OF POLLUTANTS

```
                                    POLLUTION EPISODIC MODEL (PEM-2)

   INPUT CONTROL PARAMETERS:  PEM-2 EXAMPLE 1: MULTIPLE AREA SOURCES, 2 SPECIES, 3-HR AVG CONC & DEP FLUX


   AVERAGING TIME OPTION: NTOPT=3

        A SCENARIO IS A SET OF METEOROLOGICAL DATA FOR ONE HOUR

   1  1 HOUR: CONCENTRATIONS ARE CALCULATED FOR EACH SCENARIO
   2  24 HOURS: CONCENTRATIONS CALCULATED FOR 24 SCENARIOS ARE AVERAGED
   3  VARIABLE: CONCENTRATIONS CALCULATED FOR A GIVEN NUMBER (2 TO 23) OF SCENARIOS ARE AVERAGED


WIND DIRECTION OPTION: NWDOPT=0

   0  DIRECTION IN DEGREES TO BE SPECIFIED FOR EACH SCENARIO
   1  SECTOR NUMBER TO BE SPECIFIED FOR EACH SCENARIO
  2-7 DIRECTION IN DEGREES TO BE SPECIFIED FOR THE FIRST OF FOUR SUB-SCENARIOS.
       FOR EACH SUCCEEDING SUB-SCENARIO, WIND DIRECTION IS AUTOMATICALLY INCREASED
       BY 90,45,30,15,10,OR 5 DEGREES, DEPENDING ON THE OPTION NUMBER SELECTED.


WIND SPEED OPTION: NWSOPT=0

   0  SPEED IN M/S TO BE SPECIFIED FOR EACH SCENARIO
   1  WIND SPEED CLASS NUMBER TO BE SPECIFIED FOR EACH SCENARIO

NUMBER OF SCENARIOS: NSCEN= 3

RECEPTOR GRID:      COLUMNS: LX= 25    ROWS: LY= 25
                    SPACING: GRID=  1.000 KM
                    SOUTHWEST CORNER    XRSWC=    0.0   KM W
                                        YRSWC=    0.0   KM S
```

```
                                     POLLUTION EPISODIC MODEL (PEM-2)

   INPUT CONTROL PARAMETERS:  PEM-2 EXAMPLE 1: MULTIPLE AREA SOURCES, 2 SPECIES, 3-HR AVG CONC & DEP FLUX

NUMBER OF POLLUTANTS: NPOL=2
                                    POLLUTANT-1: SO2                  POLLUTANT-2: SULFATE

AREA SOURCE SCALING FACTOR:            ASCALE=    1.000                  ASCALE=    1.000
CALIBRATION COEFFICIENTS:           A=     0.0    B=      0.0         A=     0.0    B=      0.0
CALIBRATION IDENTIFICATION:
DEPOSITION VELOCITY (CM/S):               VD1=   1.000                    VD2=   0.100
SETTLING VELOCITY (CM/S):                  W1=   0.0                       W2=   0.0


CHEMICAL TRANSFORMATION OPTION: ICT=1

   NPOL=2
     ICT=0  CHEMICAL TRANSFORMATION LOSS OF POLLUTANTS IS IGNORED
     ICT=1  FIRST-ORDER CHEMICAL TRANSFORMATION OF POLLUTANT-1 TO POLLUTANT-2 IS CONSIDERED


CHEMICAL TRANSFORMATION OR DECAY RATE: XKT=  1.000 PERCENT/HR

RATIO OF MOLECULAR WEIGHTS OF POLLUTANT-2 (PRODUCT) TO POLLUTANT-1 (REACTANT): GAMMA= 1.500

OUTPUT OPTIONS SELECTED:


   NARRAY=2  MAPS OF CONCENTRATION AND SURFACE DEPOSITION FLUX AT EACH RECEPTOR IN THE GRID,
              UNCALIBRATED ONLY
   NMAX=1    LIST OF RECEPTORS WITH HIGHEST CONCENTRATION AND SURFACE DEPOSITION FLUX
              FOR EACH SCENARIO - PRINTED AT END OF RUN
```

```
                              POLLUTION EPISODIC MODEL (PEM-2)

    INPUT SCENARIO PARAMETERS:  PEM-2 EXAMPLE 1: MULTIPLE AREA SOURCES, 2 SPECIES, 3-HR AVG CONC & DEP FLUX

                  WIND DIRECTIONS                           WIND SPEED CLASSES            STABILITY CLASSES

     SECTOR     DIRECTION       SECTOR     DIRECTION        CLASS   SPEED    CLASS              CLASS
     NUMBER       (DEG)         NUMBER       (DEG)          INDEX   (M/S)  INTERVAL(KT)         INDEX    CLASS

       1     N        0.0          9    S      180.0
       2     NNE     22.5         10    SSW    202.5          1      1.50       0-3                 1        A
       3     NE      45.0         11    SW     225.0          2      2.46       4-6                 2        B
       4     ENE     67.5         12    WSW    247.5          3      4.47        7-10               3        C
       5     E       90.0         13    W      270.0          4      6.93      11-16                4        D
       6     ESE    112.5         14    WNW    292.5          5      9.61      17-21                5        E
       7     SE     135.0         15    NW     315.0          6     12.52    OVER 21                6        F
       8     SSE    157.5         16    NNW    337.5


    SCENARIO   STABILITY   WIND SPEED   WIND        WIND      WIND       AMBIENT     TEMP GRADIENT ABOVE   MIXING
     NUMBER      CLASS       CLASS      SPEED      SECTOR   DIRECTION  TEMPERATURE      MIXING HEIGHT       HEIGHT
                                        (M/S)                 (DEG)      (DEG C)           (DEG/M)            (M)

       1           D                    4.000                225.00       5.00             0.010            550.0
       2           E                    3.000                225.00       5.00             0.010            500.0
       3           F                    2.000                225.00       5.00             0.010            500.0
```

```
                         POLLUTION EPISODIC MODEL (PEM-2)

INPUT AREA SOURCE PARAMETERS:  PEM-2 EXAMPLE 1: MULTIPLE AREA SOURCES, 2 SPECIES, 3-HR AVG CONC & DEP FLUX

                                                          POLLUTANT-1                 POLLUTANT-2
AREA SOURCE       COORDINATES       LENGTH OF SIDE       EMISSION RATE               EMISSION RATE
NUMBER          X(KM)    Y(KM)           (M)          INPUT (G/S)   SCALED        INPUT (G/S)   SCALED

   1             1.50    10.50         1000.00          10.000      10.000           1.000       1.000
   2             3.50     3.50         4000.00          90.000      90.000           9.000       9.000
   3             9.50     0.50         2000.00          20.000      20.000           2.000       2.000
   4             9.50     0.50         1000.00           5.000       5.000           0.500       0.500

        SUMS OF THE AREA SOURCE EMISSION RATES         125.000     125.000          12.500      12.500

      EFFECTIVE HEIGHT OF THE AREA SOURCE EMISSIONS =  10.00 M
```

```
                                  POLLUTION EPISODIC MODEL (PEM-2)

INPUT POINT SOURCE PARAMETERS:  PEM-2 EXAMPLE 1: MULTIPLE AREA SOURCES, 2 SPECIES, 3-HR AVG CONC & DEP FLUX


 POINT SOURCE        COORDINATES         EMISSION RATE       EMISSION RATE     HEIGHT   DIAMETER EXIT VEL   EXIT T
NUMBER    LABEL     X(KM)      Y(KM)     POLLUTANT-1 (G/S)  POLLUTANT-2 (G/S)  (M)       (M)      (M/S)     (DEG)


  SUMS OF THE POINT SOURCE EMISSION RATES    0.0    G/S          0.0    G/S
```

```
PEM-2 OUTPUT:  SECTION 1 OF 1   PEM-2 EXAMPLE 1: MULTIPLE AREA SOURCES, 2 SPECIES, 3-HR AVG CONC & DEP FLUX
3 SCENARIOS,  AVERAGING TIME=  3 HRS.                                                   POLLUTANT-1: SO2
UNCALIBRATED CONCENTRATION - MICROGRAMS PER CUBIC METER
       0.0    2.00    4.00    6.00    8.00   10.00   12.00   14.00   16.00   18.00   20.00   22.00   24.00

 24.00   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
 23.00   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
 22.00   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
 21.00   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
 20.00   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
 19.00   0   0   0   0   0   0   0   0   0   0  10   0   0   0   0   0   0   0   0   0   0   0   0   0   0
 18.00   0   0   0   0   0   0   0   0   0  11   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
 17.00   0   0   0   0   0   0   0   0  12   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
 16.00   0   0   0   0   0   0   0  14   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
 15.00   0   0   0   0   0   0  16   0   0   0   0   0   6   6   6   6   0   0   0   0   0   0   0   0   0
 14.00   0   0   0   0   0  20   0   0   0   0   0   6  12  12  12   6   0   0   0   0   0   0   0   0   0
 13.00   0   0   0   0  27   0   0   0   0   0   7  13  19  19  12   6   0   0   0   0   0   0   0   0   0
 12.00   0   0   0  48   0   0   0   0   0   8  15  21  26  19  12   6   0   0   0   0   0   0   0   0   0
 11.00   0   0  65   0   0   0   0   0   9  17  24  30  21  13   6   0   0   0   0   0   0   0   0   0   0
 10.00   0   0   0   0   0   0   0  11  21  29  35  24  15   7   0   0   0   0   5   5   0   0   0   0   0
  9.00   0   0   0   0   0   0  15  27  36  44  29  17   8   0   0   0   0   5  15   5   0   0   0   0   0
  8.00   0   0   0   0   0  27  42  54  63  36  21   9   0   0   0   0   6  17   5   0   0   0   0   0   0
  7.00   0   0   0   0  36  63  79  90  54  27  11   0   0   0   0   7  19   6   0   0   0   0   0   0   0
  6.00   0   0   0   0  36  63  79  79  42  15   0   0   0   0   8  22   7   0   0   0   0   0   0   0   0
  5.00   0   0   0   0  36  63  63  63  27   0   0   0   0  10  27   8   0   0   0   0   0   0   0   0   0
  4.00   0   0   0   0  36  36  36  36   0   0   0   0  14  34  10   0   0   0   0   0   0   0   0   0   0
  3.00   0   0   0   0   0   0   0   0   0   0   0  24  51  14   0   0   0   0   0   0   0   0   0   0   0
  2.00   0   0   0   0   0   0   0   0   0   0  32  60  24   0   0   0   0   0   0   0   0   0   0   0   0
  1.00   0   0   0   0   0   0   0   0   0   0  65  32   0   0   0   0   0   0   0   0   0   0   0   0   0
   0.0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0

       0.0    2.00    4.00    6.00    8.00    10.0   12.00   14.00   16.00   18.00   20.00   22.00   24.00
```

```
PEM-2 OUTPUT:  SECTION 1 OF 1   PEM-2 EXAMPLE 1: MULTIPLE AREA SOURCES, 2 SPECIES, 3-HR AVG CONC & DEP FLUX
3 SCENARIOS,  AVERAGING TIME=  3 HRS.                                                    POLLUTANT-1: SO2
UNCALIBRATED SURFACE DEPOSITION FLUX - KILOGRAMS PER SQUARE KILOMETER PER HOUR
        0.0      2.00      4.00      6.00      8.00     10.00     12.00     14.00     16.00     18.00     20.00     22.00     24.00

24.00    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
23.00    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
22.00    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
21.00    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
20.00    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
19.00    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
18.00    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
17.00    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
16.00    0    0    0    0    0    0    0    1    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
15.00    0    0    0    0    0    0    1    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
14.00    0    0    0    0    0    1    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
13.00    0    0    0    0    1    0    0    0    0    0    0    0    1    1    0    0    0    0    0    0    0    0    0    0    0
12.00    0    0    0    2    0    0    0    0    0    0    1    1    1    1    0    0    0    0    0    0    0    0    0    0    0
11.00    0    0    2    0    0    0    0    0    0    1    1    1    1    0    0    0    0    0    0    0    0    0    0    0    0
10.00    0    0    0    0    0    0    0    0    1    1    1    1    1    0    0    0    0    0    0    0    0    0    0    0    0
 9.00    0    0    0    0    0    0    1    1    1    2    1    1    0    0    0    0    0    0    1    0    0    0    0    0    0
 8.00    0    0    0    0    0    1    2    2    2    1    1    0    0    0    0    0    0    1    0    0    0    0    0    0    0
 7.00    0    0    0    0    1    2    3    3    2    1    0    0    0    0    0    0    1    0    0    0    0    0    0    0    0
 6.00    0    0    0    0    1    2    3    3    2    1    0    0    0    0    0    1    0    0    0    0    0    0    0    0    0
 5.00    0    0    0    0    1    2    2    2    1    0    0    0    0    0    1    0    0    0    0    0    0    0    0    0    0
 4.00    0    0    0    0    1    1    1    1    0    0    0    0    0    1    0    0    0    0    0    0    0    0    0    0    0
 3.00    0    0    0    0    0    0    0    0    0    0    0    1    2    0    0    0    0    0    0    0    0    0    0    0    0
 2.00    0    0    0    0    0    0    0    0    0    0    1    3    1    0    0    0    0    0    0    0    0    0    0    0    0
 1.00    0    0    0    0    0    0    0    0    0    0    2    1    0    0    0    0    0    0    0    0    0    0    0    0    0
  0.0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0

        0.0      2.00      4.00      6.00      8.00     10.00     12.00     14.00     16.00     18.00     20.00     22.00     24.00
```

```
PEM-2 OUTPUT:  SECTION 1 OF 1   PEM-2 EXAMPLE 1: MULTIPLE AREA SOURCES, 2 SPECIES, 3-HR AVG CONC & DEP FLUX
3  SCENARIOS,  AVERAGING TIME=  3 HRS.                                                POLLUTANT-2: SULFATE
UNCALIBRATED CONCENTRATION - MICROGRAMS PER CUBIC METER
         0.0      2.00      4.00      6.00      8.00     10.00     12.00     14.00     16.00     18.00     20.00     22.00     24.00

24.00      0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
23.00      0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
22.00      0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
21.00      0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
20.00      0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
19.00      0    0    0    0    0    0    0    0    0    0    2    0    0    0    0    0    0    0    0    0    0    0    0    0    0
18.00      0    0    0    0    0    0    0    0    0    2    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
17.00      0    0    0    0    0    0    0    0    2    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
16.00      0    0    0    0    0    0    0    2    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
15.00      0    0    0    0    0    0    2    0    0    0    0    0    1    1    1    1    0    0    0    0    0    0    0    0    0
14.00      0    0    0    0    0    3    0    0    0    0    0    1    2    2    2    1    0    0    0    0    0    0    0    0    0
13.00      0    0    0    0    4    0    0    0    0    0    1    2    3    3    2    1    0    0    0    0    0    0    0    0    0
12.00      0    0    0    6    0    0    0    0    0    1    2    3    4    3    2    1    0    0    0    0    0    0    0    0    0
11.00      0    0    7    0    0    0    0    0    1    3    4    5    3    2    1    0    0    0    0    0    0    0    0    0    0
10.00      0    0    0    0    0    0    0    2    3    4    5    4    2    1    0    0    0    0    1    1    0    0    0    0    0
 9.00      0    0    0    0    0    0    2    4    5    6    4    3    1    0    0    0    0    1    3    1    0    0    0    0    0
 8.00      0    0    0    0    0    3    5    7    8    5    3    1    0    0    0    0    1    3    1    0    0    0    0    0    0
 7.00      0    0    0    0    4    7    9   11    7    4    2    0    0    0    0    1    3    1    0    0    0    0    0    0    0
 6.00      0    0    0    0    4    7    9    9    5    2    0    0    0    0    1    3    1    0    0    0    0    0    0    0    0
 5.00      0    0    0    0    4    7    7    7    3    0    0    0    0    1    4    1    0    0    0    0    0    0    0    0    0
 4.00      0    0    0    0    4    4    4    4    0    0    0    0    2    5    1    0    0    0    0    0    0    0    0    0    0
 3.00      0    0    0    0    0    0    0    0    0    0    0    3    6    2    0    0    0    0    0    0    0    0    0    0    0
 2.00      0    0    0    0    0    0    0    0    0    0    4    9    3    0    0    0    0    0    0    0    0    0    0    0    0
 1.00      0    0    0    0    0    0    0    0    0    0    7    4    0    0    0    0    0    0    0    0    0    0    0    0    0
  0.0      0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0

         0.0      2.00      4.00      6.00      8.00     10.00     12.00     14.00     16.00     18.00     20.00     22.00     24.00
  PEM-2 OUTPUT:  SECTION 1 OF 1   PEM-2 EXAMPLE 1: MULTIPLE AREA SOURCES, 2 SPECIES, 3-HR AVG CONC & DEP FLUX
3 SCENARIOS,  AVERAGING TIME=  3 HRS.                                                  POLLUTANT-2: SULFATE
UNCALIBRATED SURFACE DEPOSITION FLUX - MICROGRAMS PER SQUARE METER PER HOUR
             0.0       2.00      4.00      6.00      8.00     10.00     12.00     14.00     16.00     18.00     20.00     22.00     24.00

  24.00      0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
  23.00      0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
  22.00      0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
  21.00      0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
  20.00      0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
  19.00      0    0    0    0    0    0    0    0    0    0    6    0    0    0    0    0    0    0    0    0    0    0    0    0    0
  18.00      0    0    0    0    0    0    0    0    0    7    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
  17.00      0    0    0    0    0    0    0    0    7    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
  16.00      0    0    0    0    0    0    0    8    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
  15.00      0    0    0    0    0    0    9    0    0    0    0    0    4    4    4    4    0    0    0    0    0    0    0    0    0
  14.00      0    0    0    0    0   10    0    0    0    0    0    4    7    7    7    4    0    0    0    0    0    0    0    0    0
  13.00      0    0    0    0   13    0    0    0    0    0    4    8   11   11    7    4    0    0    0    0    0    0    0    0    0
  12.00      0    0    0   21    0    0    0    0    0    4    8   12   16   11    7    4    0    0    0    0    0    0    0    0    0
  11.00      0    0   26    0    0    0    0    0    5    9   13   17   12    8    4    0    0    0    0    0    0    0    0    0    0
  10.00      0    0    0    0    0    0    0    6   11   15   19   13    8    4    0    0    0    0    3    3    0    0    0    0    0
   9.00      0    0    0    0    0    0    7   13   18   22   15    9    4    0    0    0    0    3   10    3    0    0    0    0    0
   8.00      0    0    0    0    0   12   19   25   30   18   11    5    0    0    0    0    4   10    3    0    0    0    0    0    0
   7.00      0    0    0    0   14   26   33   39   25   13    6    0    0    0    0    4   11    4    0    0    0    0    0    0    0
   6.00      0    0    0    0   14   26   33   33   19    7    0    0    0    0    4   12    4    0    0    0    0    0    0    0    0
   5.00      0    0    0    0   14   26   26   26   12    0    0    0    0    5   14    4    0    0    0    0    0    0    0    0    0
   4.00      0    0    0    0   14   14   14   14    0    0    0    0    6   17    5    0    0    0    0    0    0    0    0    0    0
   3.00      0    0    0    0    0    0    0    0    0    0    0   10   23    6    0    0    0    0    0    0    0    0    0    0    0
   2.00      0    0    0    0    0    0    0    0    0    0   13   33   10    0    0    0    0    0    0    0    0    0    0    0    0
   1.00      0    0    0    0    0    0    0    0    0    0   26   13    0    0    0    0    0    0    0    0    0    0    0    0    0
   0.0       0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0

             0.0       2.00      4.00      6.00      8.00     10.00     12.00     14.00     16.00     18.00     20.00     22.00     24.00
```

```
                          POLLUTION EPISODIC MODEL (PEM-2)

         OUTPUT:  PEM-2 EXAMPLE 1: MULTIPLE AREA SOURCES, 2 SPECIES, 3-HR AVG CONC & DEP FLUX

        HIGHEST PREDICTED CONCENTRATION OF EACH POLLUTANT FOR EACH SCENARIO OR AVERAGING PERIOD

        UNCALIBRATED CONCENTRATION IN MICROGRAMS PER CUBIC METER  -  CALIBRATION, POLLUTANT-1:
                                                                     CALIBRATION, POLLUTANT-2:


                              POLLUTANT-1: SO2                             POLLUTANT-2: SULFATE

SCENARIO  WIND DIRECTION    COORDINATES        CONCENTRATION          COORDINATES        CONCENTRATION
 NUMBER    SUB-SCENARIO   X(KM)     Y(KM)  UNCALIBRATED  CALIBRATED  X(KM)     Y(KM)  UNCALIBRATED  CALIBRATED

    1                      7.00      7.00     90.0691        0.0      7.00      7.00    10.8144        0.0
```

```
                              POLLUTION EPISODIC MODEL (PEM-2)

             OUTPUT:  PEM-2 EXAMPLE 1: MULTIPLE AREA SOURCES, 2 SPECIES, 3-HR AVG CONC & DEP FLUX

          HIGHEST PREDICTED SURFACE DEPOSITION FLUX OF EACH POLLUTANT FOR EACH SCENARIO OR AVERAGING PERIOD

            UNCALIBRATED VALUES IN MICROGRAMS PER SQUARE METTER PER HOUR  -  CALIBRATION, POLLUTANT-1:
                                                                             CALIBRATION, POLLUTANT-2:

                            POLLUTANT-1: SO2                                    POLLUTANT-2: SULFATE

SCENARIO  WIND DIRECTION     COORDINATES     SURFACE DEPOSITION FLUX     COORDINATES     SURFACE DEPOSITION FLUX
NUMBER    SUB-SCENARIO      X(KM)   Y(KM)  UNCALIBRATED   CALIBRATED   X(KM)   Y(KM)  UNCALIBRATED  CALIBRATED

   1                         7.00    7.00  3242.4875         0.0        7.00    7.00   38.9317        0.0
```

TABLE E-3

INPUT DATA FOR EXAMPLE PROBLEM 2A

```
                                CARD IMAGES
CONTROL CARDS
1  TITLE    PEM-2 EXAMPLE 2A: 2 POINT SOURCES, NEW PLUME RISE & PENETRATION SCHEMES
2  OPTIONS      1   1   1   0   1   0   2   0   0   1   0   1   1   1   1   1   1   0
3  GRID             0.         0.        25         25         2.         0.         0.
4  POLLUTANTS   2   1.         2.        0.         0.5        0.2        10.        1.5
5  SCALING          0.         1.        1.         0.         0.         0.         0.
6  LABLES   SO2                                     SULFATE
SCENARIO CARDS
                4   2.   9      0.         0.          25.        550.     0.001
            (A BLANK CARD TO SIGNAL END OF AREA SOURCE INVENTORY)
POINT SOURCE CARDS
           30.       2.    1000.      50.        200.          5.      10.     450. STACK 1
           10.       2.     500.      25.        200.          4.       8.     400. STACK 2
      (A BLANK CARD TO SIGNAL END OF POINT SOURCE INVENTORY)
```

TABLE E-4

OUTPUT LISTING FOR EXAMPLE PROBLEM 2A

PEM-2 (VERSION 84130)

POLLUTION EPISODIC MODEL

INCLUDING
DEPOSITION, SEDIMENTATION, AND CHEMICAL TRANSFORMATION
OF POLLUTANTS

```
                         POLLUTION EPISODIC MODEL (PEM-2)

   INPUT CONTROL PARAMETERS:  PEM-2 EXAMPLE 2A: 2 POINT SOURCES, NEW PLUME RISE & PENETRATION SCHEMES


   AVERAGING TIME OPTION: NTOPT=1

      A SCENARIO IS A SET OF METEOROLOGICAL DATA FOR ONE HOUR

    1  1 HOUR: CONCENTRATIONS ARE CALCULATED FOR EACH SCENARIO
    2  24 HOURS: CONCENTRATIONS CALCULATED FOR 24 SCENARIOS ARE AVERAGED
    3  VARIABLE: CONCENTRATIONS CALCULATED FOR A GIVEN NUMBER (2 TO 23) OF SCENARIOS ARE AVERAGED


WIND DIRECTION OPTION: NWDOPT=1

    0  DIRECTION IN DEGREES TO BE SPECIFIED FOR EACH SCENARIO
    1  SECTOR NUMBER TO BE SPECIFIED FOR EACH SCENARIO
  2-7  DIRECTION IN DEGREES TO BE SPECIFIED FOR THE FIRST OF FOUR SUB-SCENARIOS.
        FOR EACH SUCCEEDING SUB-SCENARIO, WIND DIRECTION IS AUTOMATICALLY INCREASED
        BY 90,45,30,15,10,OR 5 DEGREES, DEPENDING ON THE OPTION NUMBER SELECTED.


WIND SPEED OPTION: NWSOPT=1

    0  SPEED IN M/S TO BE SPECIFIED FOR EACH SCENARIO
    1  WIND SPEED CLASS NUMBER TO BE SPECIFIED FOR EACH SCENARIO


NUMBER OF SCENARIOS: NSCEN= 1


RECEPTOR GRID:       COLUMNS: LX= 25    ROWS: LY= 25
                     SPACING: GRID=  2.000 KM
                     SOUTHWEST CORNER    XRSWC=     0.0   KM W
                                         YRSWC=     0.0   KM S
```

```
                              POLLUTION EPISODIC MODEL (PEM-2)

    INPUT CONTROL PARAMETERS:  PEM-2 EXAMPLE 2A: 2 POINT SOURCES, NEW PLUME RISE & PENETRATION SCHEMES

NUMBER OF POLLUTANTS: NPOL=2
                                   POLLUTANT-1: SO2                  POLLUTANT-2: SULFATE

AREA SOURCE SCALING FACTOR:           ASCALE=    1.000                  ASCALE=    1.000

CALIBRATION COEFFICIENTS:          A=      0.0    B=      0.0        A=      0.0    B=      0.0

CALIBRATION IDENTIFICATION:

DEPOSITION VELOCITY (CM/S):              VD1=   2.000                     VD2=   0.500

SETTLING VELOCITY (CM/S):                 W1=   0.0                        W2=   0.200

CHEMICAL TRANSFORMATION OPTION: ICT=1

   NPOL=2
     ICT=0  CHEMICAL TRANSFORMATION LOSS OF POLLUTANTS IS IGNORED
     ICT=1  FIRST-ORDER CHEMICAL TRANSFORMATION OF POLLUTANT-1 TO POLLUTANT-2 IS CONSIDERED

CHEMICAL TRANSFORMATION OR DECAY RATE: XKT= 10.000 PERCENT/HR

RATIO OF MOLECULAR WEIGHTS OF POLLUTANT-2 (PRODUCT) TO POLLUTANT-1 (REACTANT): GAMMA= 1.500

OUTPUT OPTIONS SELECTED:

   NARRAY=2  MAPS OF CONCENTRATION AND SURFACE DEPOSITION FLUX AT EACH RECEPTOR IN THE GRID,
              UNCALIBRATED ONLY
   NMAX=1    LIST OF RECEPTORS WITH HIGHEST CONCENTRATION AND SURFACE DEPOSITION FLUX
              FOR EACH SCENARIO - PRINTED AT END OF RUN
```

```
                              POLLUTION EPISODIC MODEL (PEM-2)

   INPUT SCENARIO PARAMETERS:  PEM-2 EXAMPLE 2A: 2 POINT SOURCES, NEW PLUME RISE & PENETRATION SCHEMES

                  WIND DIRECTIONS                          WIND SPEED CLASSES           STABILITY CLASSES

 SECTOR      DIRECTION      SECTOR     DIRECTION        CLASS   SPEED     CLASS            CLASS
 NUMBER          (DEG)      NUMBER         (DEG)        INDEX   (M/S)   INTERVAL(KT)       INDEX    CLASS

    1     N        0.0         9      S     180.0
    2     NNE     22.5        10      SSW   202.5          1     1.50        0-3              1        A
    3     NE      45.0        11      SW    225.0          2     2.46        4-6              2        B
    4     ENE     67.5        12      WSW   247.5          3     4.47        7-10             3        C
    5     E       90.0        13      W     270.0          4     6.93       11-16             4        D
    6     ESE    112.5        14      WNW   292.5          5     9.61       17-21             5        E
    7     SE     135.0        15      NW    315.0          6    12.52     OVER 21             6        F
    8     SSE    157.5        16      NNW   337.5


 SCENARIO   STABILITY   WIND SPEED    WIND      WIND      WIND        AMBIENT     TEMP GRADIENT ABOVE   MIXING
  NUMBER      CLASS       CLASS       SPEED    SECTOR   DIRECTION   TEMPERATURE     MIXING HEIGHT       HEIGHT
                                      (M/S)               (DEG)       (DEG C)          (DEG/M)            (M)

    1           D           2                    9                     25.00            0.001           550.0
```

```
                          POLLUTION EPISODIC MODEL (PEM-2)

   INPUT AREA SOURCE PARAMETERS:  PEM-2 EXAMPLE 2A: 2 POINT SOURCES, NEW PLUME RISE & PENETRATION SCHEMES

                                                                POLLUTANT-1            POLLUTANT-2
   AREA SOURCE       COORDINATES        LENGTH OF SIDE         EMISSION RATE          EMISSION RATE
     NUMBER        X(KM)     Y(KM)           (M)             INPUT (G/S)   SCALED   INPUT (G/S)   SCALED

                SUMS OF THE AREA SOURCE EMISSION RATES          0.0          0.0        0.0          0.0

               EFFECTIVE HEIGHT OF THE AREA SOURCE EMISSIONS =  0.0  M
```

```
                                    POLLUTION EPISODIC MODEL (PEM-2)
    INPUT POINT SOURCE PARAMETERS:  PEM-2 EXAMPLE 2A: 2 POINT SOURCES, NEW PLUME RISE & PENETRATION SCHEMES

 POINT  SOURCE        COORDINATES        EMISSION RATE        EMISSION RATE      HEIGHT  DIAMETER  EXIT VEL  EXIT TEMP
NUMBER   LABEL      X(KM)     Y(KM)    POLLUTANT-1 (G/S)   POLLUTANT-2 (G/S)    (M)      (M)      (M/S)    (DEG C)

   1    STACK 1     30.00      2.00         1000.000              50.000       200.00    5.000    10.000     450.0
   2    STACK 2     10.00      2.00          500.000              25.000       200.00    4.000     8.000     400.0

 SUMS OF THE POINT SOURCE EMISSION RATES    1500.000 G/S          75.000 G/S

 INPUT CONTROL PARAMETERS:

   WIND PROFILE EXPONENTS OPTION: NWPOPT=0
      0  EXPONENTS AND ANEMOMETER HEIGHT ARE STANDARD DEFAULT VALUES
      1  EXPONENTS AND ANEMOMETER HEIGHT TO BE SPECIFIED BY THE USER

   STACK-TIP DOWNWASH ALGORITHM OPTION: NSTDWN=0
      0  ALGORITHM IS IN EFFECT
      1  ALGORITHM IS NOT USED

   NEW PLUME-RISE EQUATIONS OPTION: NPRISE=1
      0  STANDARD PLUME-RISE EQS. ARE USED FOR ALL STABILITY CLASSES
      1  NEW EQS. ARE USED FOR PEAK BUOYANCY RISE FOR STABILITY CLASSES A-D

   POTENTIAL TEMPERATURE GRADIENT: DTDZ(1)=   0.020 DEG/M    STABILITY CLASS E
                                   DTDZ(2)=   0.035 DEG/M    STABILITY CLASS F

   PLUME PENETRATION ABOVE MIXING HEIGHT OPTION: NINPEN=1
      0  STANDARD TREATMENT OF PLUME PENETRATION ABOVE THE MIXING HEIGHT
      1  NEW SCHEMES FOR PLUME PENETRATION OF ELEVATED STABLE LAYER USED
           FOR STABILITY CLASSES A-D AND BUOYANCY-DOMINATED PLUME

   OUTPUT OPTIONS SELECTED:

      NPRINT=1  LIST OF POINT SOURCE PARAMETERS AND EFFECTIVE STACK HEIGHTS
                  PRINTED AT BEGINNING OF EACH SCENARIO

     FINAL EFFECTIVE PLUME RISE USED: NGPR =1
     BOUYANCY INDUCED DISPERSION FOR NBID=1: NBID= 0
```

```
                                   POLLUTION EPISODIC MODEL (PEM-2)

                     OUTPUT:  PEM-2 EXAMPLE 2A: 2 POINT SOURCES, NEW PLUME RISE & PENETRATION SCHEMES

    SCENARIO 1       POINT SOURCE PLUME RISE CALCULATIONS
                      MIXING HEIGHT: HMIX= 550.00 M
                      POTENTIAL TEMPERATURE GRADIENT ABOVE MIXING HEIGHT=0.0010 DEG/M

              SOURCE      EMISSION RATES STACK     EXIT      EXIT     EXIT              WIND SPEED AT  MAX.EFF.     PLUME
   POINT   COORDINATES  POL-1    POL-2  HEIGHT DIAMETER VELOCITY  TEMP.   DOMINANT  STACK HEIGHT  SOURCE HT. PENETRATION
   SOURCE X(KM)   Y(KM) (G/S)    (G/S)   (M)      (M)     (M/S)   (DEG K) INFLUENCE     (M/S)         (M)      FRACTION

     1     30.0     2.0  550.4    27.5  200.0    5.00    10.00  723.15   BUOYANCY      5.20        458.30      0.450
     2     10.0     2.0  418.3    20.9  200.0    4.00     8.00  673.15   BUOYANCY      5.20        440.47      0.163
```

```
PEM-2 OUTPUT: SECTION 1 OF 1, SCENARIO 1  PEM-2 EXAMPLE 2A: 2 POINT SOURCES, NEW PLUME RISE & PENETRATION SCHEMES
STABILITY=D , WIND SPD= 2.46 M/S, WIND DIR=180.00 DEG, MIXING HT=  550.0 M, AVERAGING TIME= 1 HR.  POLLUTANT-1: SO2
UNCALIBRATED CONCENTRATION - MICROGRAMS PER CUBIC METER
             0.0      4.00      8.00     12.00     16.00     20.00     24.00     28.00     32.00     36.00     40.00     44.00     48.00

  48.00        0    0    0    1   11   23   11    1    0    0    0    0    0    2   15   31   15    2    0    0    0    0    0    0    0
  46.00        0    0    0    1   11   24   11    1    0    0    0    0    0    2   15   32   15    2    0    0    0    0    0    0    0
  44.00        0    0    0    1   11   25   11    1    0    0    0    0    0    1   15   33   15    1    0    0    0    0    0    0    0
  42.00        0    0    0    1   11   26   11    1    0    0    0    0    0    1   15   34   15    1    0    0    0    0    0    0    0
  40.00        0    0    0    1   11   27   11    1    0    0    0    0    0    1   15   36   15    1    0    0    0    0    0    0    0
  38.00        0    0    0    1   11   28   11    1    0    0    0    0    0    1   15   37   15    1    0    0    0    0    0    0    0
  36.00        0    0    0    1   11   30   11    1    0    0    0    0    0    1   15   39   15    1    0    0    0    0    0    0    0
  34.00        0    0    0    0   11   31   11    0    0    0    0    0    0    1   14   41   14    1    0    0    0    0    0    0    0
  32.00        0    0    0    0   11   33   11    0    0    0    0    0    0    0   14   43   14    0    0    0    0    0    0    0    0
  30.00        0    0    0    0   10   34   10    0    0    0    0    0    0    0   13   45   13    0    0    0    0    0    0    0    0
  28.00        0    0    0    0   10   36   10    0    0    0    0    0    0    0   13   48   13    0    0    0    0    0    0    0    0
  26.00        0    0    0    0    9   39    9    0    0    0    0    0    0    0   12   51   12    0    0    0    0    0    0    0    0
  24.00        0    0    0    0    8   41    8    0    0    0    0    0    0    0   11   54   11    0    0    0    0    0    0    0    0
  22.00        0    0    0    0    8   44    8    0    0    0    0    0    0    0   10   58   10    0    0    0    0    0    0    0    0
  20.00        0    0    0    0    7   47    7    0    0    0    0    0    0    0    9   62    9    0    0    0    0    0    0    0    0
  18.00        0    0    0    0    5   51    5    0    0    0    0    0    0    0    7   68    7    0    0    0    0    0    0    0    0
  16.00        0    0    0    0    4   56    4    0    0    0    0    0    0    0    5   74    5    0    0    0    0    0    0    0    0
  14.00        0    0    0    0    3   63    3    0    0    0    0    0    0    0    4   82    4    0    0    0    0    0    0    0    0
  12.00        0    0    0    0    1   71    1    0    0    0    0    0    0    0    2   93    2    0    0    0    0    0    0    0    0
  10.00        0    0    0    0    0   83    0    0    0    0    0    0    0    0    1  109    1    0    0    0    0    0    0    0    0
   8.00        0    0    0    0    0  101    0    0    0    0    0    0    0    0    0  133    0    0    0    0    0    0    0    0    0
   6.00        0    0    0    0    0  105    0    0    0    0    0    0    0    0    0  133    0    0    0    0    0    0    0    0    0
   4.00        0    0    0    0    0   64    0    0    0    0    0    0    0    0    0   72    0    0    0    0    0    0    0    0    0
   2.00        0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
   0.0         0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0

             0.0      4.00      8.00     12.00     16.00     20.00     24.00     28.00     32.00     36.00     40.00     44.00     48.00
```

```
PEM-2 OUTPUT: SECTION 1 OF 1, SCENARIO 1  PEM-2 EXAMPLE 2A: 2 POINT SOURCES, NEW PLUME RISE & PENETRATION SCHEMES
STABILITY=D , WIND SPD= 2.46 M/S, WIND DIR=180.00 DEG, MIXING HT=  550.0 M, AVERAGING TIME= 1 HR.  POLLUTANT-1: SO2
UNCALIBRATED SURFACE DEPOSITION FLUX - KILOGRAMS PER SQUARE KILOMETER PER HOUR
              0.0       4.00      8.00     12.00     16.00     20.00     24.00     28.00     32.00     36.00     40.00     44.00     48.00

  48.00         0    0    0    0    1    2    1    0    0    0    0    0    0    0    1    2    1    0    0    0    0    0    0    0    0
  46.00         0    0    0    0    1    2    1    0    0    0    0    0    0    0    1    2    1    0    0    0    0    0    0    0    0
  44.00         0    0    0    0    1    2    1    0    0    0    0    0    0    0    1    2    1    0    0    0    0    0    0    0    0
  42.00         0    0    0    0    1    2    1    0    0    0    0    0    0    0    1    2    1    0    0    0    0    0    0    0    0
  40.00         0    0    0    0    1    2    1    0    0    0    0    0    0    0    1    3    1    0    0    0    0    0    0    0    0
  38.00         0    0    0    0    1    2    1    0    0    0    0    0    0    0    1    3    1    0    0    0    0    0    0    0    0
  36.00         0    0    0    0    1    2    1    0    0    0    0    0    0    0    1    3    1    0    0    0    0    0    0    0    0
  34.00         0    0    0    0    1    2    1    0    0    0    0    0    0    0    1    3    1    0    0    0    0    0    0    0    0
  32.00         0    0    0    0    1    2    1    0    0    0    0    0    0    0    1    3    1    0    0    0    0    0    0    0    0
  30.00         0    0    0    0    1    2    1    0    0    0    0    0    0    0    1    3    1    0    0    0    0    0    0    0    0
  28.00         0    0    0    0    1    3    1    0    0    0    0    0    0    0    1    3    1    0    0    0    0    0    0    0    0
  26.00         0    0    0    0    1    3    1    0    0    0    0    0    0    0    1    4    1    0    0    0    0    0    0    0    0
  24.00         0    0    0    0    1    3    1    0    0    0    0    0    0    0    1    4    1    0    0    0    0    0    0    0    0
  22.00         0    0    0    0    1    3    1    0    0    0    0    0    0    0    1    4    1    0    0    0    0    0    0    0    0
  20.00         0    0    0    0    0    3    0    0    0    0    0    0    0    0    1    4    1    0    0    0    0    0    0    0    0
  18.00         0    0    0    0    0    4    0    0    0    0    0    0    0    0    1    5    1    0    0    0    0    0    0    0    0
  16.00         0    0    0    0    0    4    0    0    0    0    0    0    0    0    0    5    0    0    0    0    0    0    0    0    0
  14.00         0    0    0    0    0    5    0    0    0    0    0    0    0    0    0    6    0    0    0    0    0    0    0    0    0
  12.00         0    0    0    0    0    5    0    0    0    0    0    0    0    0    0    7    0    0    0    0    0    0    0    0    0
  10.00         0    0    0    0    0    6    0    0    0    0    0    0    0    0    0    8    0    0    0    0    0    0    0    0    0
   8.00         0    0    0    0    0    7    0    0    0    0    0    0    0    0    0   10    0    0    0    0    0    0    0    0    0
   6.00         0    0    0    0    0    8    0    0    0    0    0    0    0    0    0   10    0    0    0    0    0    0    0    0    0
   4.00         0    0    0    0    0    5    0    0    0    0    0    0    0    0    0    5    0    0    0    0    0    0    0    0    0
   2.00         0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
   0.0          0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0

              0.0       4.00      8.00     12.00     16.00     20.00     24.00     28.00     32.00     36.00     40.00     44.00     48.00
```

```
PEM-2 OUTPUT: SECTION 1 OF 1, SCENARIO 1  PEM-2 EXAMPLE 2A: 2 POINT SOURCES, NEW PLUME RISE & PENETRATION SCHEMES
STABILITY=D, WIND SPD= 2.46 M/S, WIND DIR=180.00 DEG, MIXING HT= 550.0 M, AVERAGING TIME= 1 HR. POLLUTANT-2: SULFATE
UNCALIBRATED CONCENTRATION - MICROGRAMS PER CUBIC METER
            0.0       4.00      8.00     12.00     16.00     20.00     24.00     28.00     32.00     36.00     40.00     44.00     48.00

   48.00      0    0    0    1    6   12    6    1    0    0    0    0    0    1    8   15    8    1    0    0    0    0    0    0    0
   46.00      0    0    0    1    5   12    5    1    0    0    0    0    0    1    7   15    7    1    0    0    0    0    0    0    0
   44.00      0    0    0    0    5   11    5    0    0    0    0    0    0    1    7   15    7    1    0    0    0    0    0    0    0
   42.00      0    0    0    0    5   11    5    0    0    0    0    0    0    1    7   15    7    1    0    0    0    0    0    0    0
   40.00      0    0    0    0    5   11    5    0    0    0    0    0    0    0    6   15    6    0    0    0    0    0    0    0    0
   38.00      0    0    0    0    4   11    4    0    0    0    0    0    0    0    6   15    6    0    0    0    0    0    0    0    0
   36.00      0    0    0    0    4   11    4    0    0    0    0    0    0    0    5   15    5    0    0    0    0    0    0    0    0
   34.00      0    0    0    0    4   11    4    0    0    0    0    0    0    0    5   14    5    0    0    0    0    0    0    0    0
   32.00      0    0    0    0    4   11    4    0    0    0    0    0    0    0    5   14    5    0    0    0    0    0    0    0    0
   30.00      0    0    0    0    3   11    3    0    0    0    0    0    0    0    4   14    4    0    0    0    0    0    0    0    0
   28.00      0    0    0    0    3   11    3    0    0    0    0    0    0    0    4   14    4    0    0    0    0    0    0    0    0
   26.00      0    0    0    0    2   10    2    0    0    0    0    0    0    0    3   14    3    0    0    0    0    0    0    0    0
   24.00      0    0    0    0    2   10    2    0    0    0    0    0    0    0    3   14    3    0    0    0    0    0    0    0    0
   22.00      0    0    0    0    2   10    2    0    0    0    0    0    0    0    2   13    2    0    0    0    0    0    0    0    0
   20.00      0    0    0    0    1   10    1    0    0    0    0    0    0    0    2   13    2    0    0    0    0    0    0    0    0
   18.00      0    0    0    0    1   10    1    0    0    0    0    0    0    0    1   13    1    0    0    0    0    0    0    0    0
   16.00      0    0    0    0    1   10    1    0    0    0    0    0    0    0    1   13    1    0    0    0    0    0    0    0    0
   14.00      0    0    0    0    0   10    0    0    0    0    0    0    0    0    1   13    1    0    0    0    0    0    0    0    0
   12.00      0    0    0    0    0   10    0    0    0    0    0    0    0    0    0   13    0    0    0    0    0    0    0    0    0
   10.00      0    0    0    0    0   10    0    0    0    0    0    0    0    0    0   13    0    0    0    0    0    0    0    0    0
    8.00      0    0    0    0    0   10    0    0    0    0    0    0    0    0    0   14    0    0    0    0    0    0    0    0    0
    6.00      0    0    0    0    0    9    0    0    0    0    0    0    0    0    0   12    0    0    0    0    0    0    0    0    0
    4.00      0    0    0    0    0    4    0    0    0    0    0    0    0    0    0    5    0    0    0    0    0    0    0    0    0
    2.00      0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
    0.0       0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0

            0.0       4.00      8.00     12.00     16.00     20.00     24.00     28.00     32.00     36.00     40.00     44.00     48.00
```

```
PEM-2 OUTPUT: SECTION 1 OF 1, SCENARIO 1  PEM-2 EXAMPLE 2A: 2 POINT SOURCES, NEW PLUME RISE & PENETRATION SCHEMES
STABILITY=D, WIND SPD= 2.46 M/S, WIND DIR=180.00 DEG, MIXING HT= 550.0 M, AVERAGING TIME= 1 HR. POLLUTANT-2: SULFATE
UNCALIBRATED SURFACE DEPOSITION FLUX - MICROGRAMS PER SQUARE METER PER HOUR
            0.0    4.00    8.00   12.00   16.00   20.00   24.00   28.00   32.00   36.00   40.00   44.00   48.00

  48.00       0   0   0  12 103 210 103  12   0   0   0   0   0  16 135 277 135  16   0   0   0   0   0   0   0
  46.00       0   0   0  10  98 209  98  10   0   0   0   0   0  14 130 274 130  14   0   0   0   0   0   0   0
  44.00       0   0   0   9  94 207  94   9   0   0   0   0   0  12 124 272 124  12   0   0   0   0   0   0   0
  42.00       0   0   0   7  89 205  89   7   0   0   0   0   0  10 118 270 118  10   0   0   0   0   0   0   0
  40.00       0   0   0   6  85 203  85   6   0   0   0   0   0   8 111 267 111   8   0   0   0   0   0   0   0
  38.00       0   0   0   5  80 201  80   5   0   0   0   0   0   6 105 265 105   6   0   0   0   0   0   0   0
  36.00       0   0   0   4  74 199  74   4   0   0   0   0   0   5  98 262  98   5   0   0   0   0   0   0   0
  34.00       0   0   0   3  69 197  69   3   0   0   0   0   0   4  91 260  91   4   0   0   0   0   0   0   0
  32.00       0   0   0   2  63 195  63   2   0   0   0   0   0   3  83 257  83   3   0   0   0   0   0   0   0
  30.00       0   0   0   1  57 193  57   1   0   0   0   0   0   2  75 254  75   2   0   0   0   0   0   0   0
  28.00       0   0   0   1  51 191  51   1   0   0   0   0   0   1  67 251  67   1   0   0   0   0   0   0   0
  26.00       0   0   0   1  45 189  45   1   0   0   0   0   0   1  59 248  59   1   0   0   0   0   0   0   0
  24.00       0   0   0   0  38 186  38   0   0   0   0   0   0   0  50 245  50   0   0   0   0   0   0   0   0
  22.00       0   0   0   0  32 184  32   0   0   0   0   0   0   0  42 242  42   0   0   0   0   0   0   0   0
  20.00       0   0   0   0  25 182  25   0   0   0   0   0   0   0  33 240  33   0   0   0   0   0   0   0   0
  18.00       0   0   0   0  19 180  19   0   0   0   0   0   0   0  25 237  25   0   0   0   0   0   0   0   0
  16.00       0   0   0   0  13 179  13   0   0   0   0   0   0   0  17 235  17   0   0   0   0   0   0   0   0
  14.00       0   0   0   0   8 178   8   0   0   0   0   0   0   0  10 234  10   0   0   0   0   0   0   0   0
  12.00       0   0   0   0   4 178   4   0   0   0   0   0   0   0   5 235   5   0   0   0   0   0   0   0   0
  10.00       0   0   0   0   1 181   1   0   0   0   0   0   0   0   1 238   1   0   0   0   0   0   0   0   0
   8.00       0   0   0   0   0 189   0   0   0   0   0   0   0   0   0 249   0   0   0   0   0   0   0   0   0
   6.00       0   0   0   0   0 165   0   0   0   0   0   0   0   0   0 210   0   0   0   0   0   0   0   0   0
   4.00       0   0   0   0   0  79   0   0   0   0   0   0   0   0   0  89   0   0   0   0   0   0   0   0   0
   2.00       0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0.0        0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0

            0.0    4.00    8.00   12.00   16.00   20.00   24.00   28.00   32.00   36.00   40.00   44.00   48.00
```

```
                                 POLLUTION EPISODIC MODEL (PEM-2)

                OUTPUT:  PEM-2 EXAMPLE 2A: 2 POINT SOURCES, NEW PLUME RISE & PENETRATION SCHEMES

             HIGHEST PREDICTED CONCENTRATION OF EACH POLLUTANT FOR EACH SCENARIO OR AVERAGING PERIOD

              UNCALIBRATED CONCENTRATION IN MICROGRAMS PER CUBIC METER  -  CALIBRATION, POLLUTANT-1:
                                                                           CALIBRATION, POLLUTANT-2:


                        POLLUTANT-1: SO2                                 POLLUTANT-2: SULFATE

SCENARIO  WIND DIRECTION   COORDINATES       CONCENTRATION          COORDINATES       CONCENTRATION
 NUMBER    SUB-SCENARIO   X(KM)    Y(KM)  UNCALIBRATED   CALIBRATED  X(KM)    Y(KM)  UNCALIBRATED  CALIBRATED


   1                      30.00     6.00   133.3774          0.0     30.00    48.00   15.3673          0.0
```

```
                              POLLUTION EPISODIC MODEL (PEM-2)

            OUTPUT:  PEM-2 EXAMPLE 2A: 2 POINT SOURCES, NEW PLUME RISE & PENETRATION SCHEMES

      HIGHEST PREDICTED SURFACE DEPOSITION FLUX OF EACH POLLUTANT FOR EACH SCENARIO OR AVERAGING PERIOD

        UNCALIBRATED VALUES IN MICROGRAMS PER SQUARE METER PER HOUR  -  CALIBRATION, POLLUTANT-1:
                                                                        CALIBRATION, POLLUTANT-2:

                          POLLUTANT-1: SO2                                       POLLUTANT-2: SULFATE

SCENARIO  WIND DIRECTION    COORDINATES      SURFACE DEPOSITION FLUX      COORDINATES      SURFACE DEPOSITION FLUX
 NUMBER   SUB-SCENARIO    X(KM)     Y(KM)  UNCALIBRATED    CALIBRATED  X(KM)     Y(KM)  UNCALIBRATED    CALIBRATED

    1                     30.00      6.00  9603.1719          0.0      30.00     48.00     276.6121         0.0
```

TABLE E-5

INPUT DATA FOR EXAMPLE PROBLEM 2B

CARD IMAGES

```
CONTROL CARDS
1  TITLE   PEM-2 EXAMPLE 2B: 2 POINT SOURCES, STANDARD PLUME RISE & PENETRATION SCHEMES
2  OPTIONS    1   1   1   0   1   0   2   0   0   1   0   0   0   1   1   1   1   0
3  GRID           0.          0.          25          25          2.          0.          0.
4  POLLUTANTS  2  1.          2.          0.          0.5         0.2         10.         1.5
5  SCALING        0.          1.          1.          0.          0.          0.          0.
6  LABLES  SO2                                        SULFATE
SCENARIO CARDS
                4   2.   9        0.         0.          25.          550.     0.001
             (A BLANK CARD TO SIGNAL END OF AREA SOURCE INVENTORY)
POINT SOURCE CARDS
            30.       2.    1000.      50.       200.         5.     10.     450. STACK 1
            10.       2.     500.      25.       200.         4.      8.     400. STACK 2
      (A BLANK CARD TO SIGNAL END OF POINT SOURCE INVENTORY)
```

TABLE E-6

OUTPUT LISTING FOR EXAMPLE PROBLEM 2B

PEM-2 (VERSION 84130)

POLLUTION EPISODIC MODEL

INCLUDING

DEPOSITION, SEDIMENTATION, AND CHEMICAL TRANSFORMATION

OF POLLUTANTS

```
                              POLLUTION EPISODIC MODEL (PEM-2)

  INPUT CONTROL PARAMETERS:  PEM-2 EXAMPLE 2B: 2 POINT SOURCES, STANDARD PLUME RISE & PENETRATION SCHEMES

 AVERAGING TIME OPTION: NTOPT=1

        A SCENARIO IS A SET OF METEOROLOGICAL DATA FOR ONE HOUR

   1  1 HOUR: CONCENTRATIONS ARE CALCULATED FOR EACH SCENARIO
   2  24 HOURS: CONCENTRATIONS CALCULATED FOR 24 SCENARIOS ARE AVERAGED
   3  VARIABLE: CONCENTRATIONS CALCULATED FOR A GIVEN NUMBER (2 TO 23) OF SCENARIOS ARE AVERAGED

 WIND DIRECTION OPTION: NWDOPT=1

   0  DIRECTION IN DEGREES TO BE SPECIFIED FOR EACH SCENARIO
   1  SECTOR NUMBER TO BE SPECIFIED FOR EACH SCENARIO
  2-7 DIRECTION IN DEGREES TO BE SPECIFIED FOR THE FIRST OF FOUR SUB-SCENARIOS.
        FOR EACH SUCCEEDING SUB-SCENARIO, WIND DIRECTION IS AUTOMATICALLY INCREASED
        BY 90,45,30,15,10,OR 5 DEGREES, DEPENDING ON THE OPTION NUMBER SELECTED.

 WIND SPEED OPTION: NWSOPT=1

   0  SPEED IN M/S TO BE SPECIFIED FOR EACH SCENARIO
   1  WIND SPEED CLASS NUMBER TO BE SPECIFIED FOR EACH SCENARIO

 NUMBER OF SCENARIOS: NSCEN= 1

 RECEPTOR GRID:       COLUMNS: LX= 25    ROWS: LY= 25
                      SPACING: GRID=  2.000 KM
                      SOUTHWEST CORNER    XRSWC=    0.0    KM W
                                          YRSWC=    0.0    KM S
                              POLLUTION EPISODIC MODEL (PEM-2)

INPUT CONTROL PARAMETERS:  PEM-2 EXAMPLE 2B: 2 POINT SOURCES, STANDARD PLUME RISE & PENETRATION SCHEMES

NUMBER OF POLLUTANTS: NPOL=2                                          POLLUTANT-2: SULFATE
                                 POLLUTANT-1: SO2

                                                                        ASCALE=    1.000
AREA SOURCE SCALING FACTOR:          ASCALE=    1.000
                                                                  A=      0.0    B=      0.0
CALIBRATION COEFFICIENTS:       A=      0.0    B=      0.0

CALIBRATION IDENTIFICATION:
                                                                         VD2=   0.500
DEPOSITION VELOCITY (CM/S):              VD1=   2.000
                                                                          W2=   0.200
SETTLING VELOCITY (CM/S):                 W1=   0.0


CHEMICAL TRANSFORMATION OPTION: ICT=1

  NPOL=2
    ICT=0  CHEMICAL TRANSFORMATION LOSS OF POLLUTANTS IS IGNORED
    ICT=1  FIRST-ORDER CHEMICAL TRANSFORMATION OF POLLUTANT-1 TO POLLUTANT-2 IS CONSIDERED

CHEMICAL TRANSFORMATION OR DECAY RATE: XKT= 10.000 PERCENT/HR

RATIO OF MOLECULAR WEIGHTS OF POLLUTANT-2 (PRODUCT) TO POLLUTANT-1 (REACTANT): GAMMA= 1.500

OUTPUT OPTIONS SELECTED:

  NARRAY=2  MAPS OF CONCENTRATION AND SURFACE DEPOSITION FLUX AT EACH RECEPTOR IN THE GRID,
             UNCALIBRATED ONLY
  NMAX=1    LIST OF RECEPTORS WITH HIGHEST CONCENTRATION AND SURFACE DEPOSITION FLUX
             FOR EACH SCENARIO - PRINTED AT END OF RUN
```

```
                                   POLLUTION EPISODIC MODEL (PEM-2)

INPUT SCENARIO PARAMETERS:  PEM-2 EXAMPLE 2B: 2 POINT SOURCES, STANDARD PLUME RISE & PENETRATION SCHEMES

             WIND DIRECTIONS                          WIND SPEED CLASSES          STABILITY CLASSES

SECTOR    DIRECTION      SECTOR    DIRECTION         CLASS   SPEED    CLASS            CLASS
NUMBER        (DEG)      NUMBER        (DEG)         INDEX   (M/S)   INTERVAL(KT)      INDEX   CLASS

   1    N       0.0         9    S     180.0
   2    NNE    22.5        10    SSW   202.5           1      1.50      0-3              1       A
   3    NE     45.0        11    SW    225.0           2      2.46      4-6              2       B
   4    ENE    67.5        12    WSW   247.5           3      4.47      7-10             3       C
   5    E      90.0        13    W     270.0           4      6.93     11-16             4       D
   6    ESE   112.5        14    WNW   292.5           5      9.61     17-21             5       E
   7    SE    135.0        15    NW    315.0           6     12.52    OVER 21            6       F
   8    SSE   157.5        16    NNW   337.5


SCENARIO  STABILITY  WIND SPEED     WIND     WIND      WIND       AMBIENT    TEMP GRADIENT ABOVE  MIXING
 NUMBER     CLASS      CLASS       SPEED    SECTOR  DIRECTION  TEMPERATURE     MIXING HEIGHT      HEIGHT
                                   (M/S)              (DEG)      (DEG C)          (DEG/M)           (M)

   1          D          2                    9                   25.00                            550.0
```

```
                              POLLUTION EPISODIC MODEL (PEM-2)

INPUT AREA SOURCE PARAMETERS:  PEM-2 EXAMPLE 2B: 2 POINT SOURCES, STANDARD PLUME RISE & PENETRATION SCHEMES

                                                                POLLUTANT-1               POLLUTANT-2
 AREA SOURCE       COORDINATES        LENGTH OF SIDE          EMISSION RATE             EMISSION RATE
   NUMBER       X(KM)      Y(KM)           (M)             INPUT (G/S)    SCALED     INPUT (G/S)    SCALED

              SUMS OF THE AREA SOURCE EMISSION RATES            0.0          0.0          0.0          0.0

          EFFECTIVE HEIGHT OF THE AREA SOURCE EMISSIONS =    0.0  M
```

```
                                    POLLUTION EPISODIC MODEL (PEM-2)

  INPUT POINT SOURCE PARAMETERS:  PEM-2 EXAMPLE 2B: 2 POINT SOURCES, STANDARD PLUME RISE & PENETRATION SCHEMES

 POINT  SOURCE      COORDINATES        EMISSION RATE         EMISSION RATE      HEIGHT   DIAMETER   EXIT VEL   EXIT TEMP
NUMBER   LABEL     X(KM)     Y(KM)   POLLUTANT-1 (G/S)   POLLUTANT-2 (G/S)     (M)       (M)       (M/S)     (DEG  C)

   1     STACK 1   30.00      2.00         1000.000              50.000       200.00     5.000      10.000     450.000
   2     STACK 2   10.00      2.00          500.000              25.000       200.00     4.000       8.000     400.000

SUMS OF THE POINT SOURCE EMISSION RATES  1500.000 G/S            75.000 G/S

INPUT CONTROL PARAMETERS:

  WIND PROFILE EXPONENTS OPTION: NWPOPT=0
     0  EXPONENTS AND ANEMOMETER HEIGHT ARE STANDARD DEFAULT VALUES
     1  EXPONENTS AND ANEMOMETER HEIGHT TO BE SPECIFIED BY THE USER

  STACK-TIP DOWNWASH ALGORITHM OPTION: NSTDWN=0
     0  ALGORITHM IS IN EFFECT
     1  ALGORITHM IS NOT USED

  NEW PLUME-RISE EQUATIONS OPTION: NPRISE=0
     0  STANDARD PLUME-RISE EQS. ARE USED FOR ALL STABILITY CLASSES
     1  NEW EQS. ARE USED FOR PEAK BUOYANCY RISE FOR STABILITY CLASSES A-D

  POTENTIAL TEMPERATURE GRADIENT: DTDZ(1)=   0.020 DEG/M    STABILITY CLASS E
                                  DTDZ(2)=   0.035 DEG/M    STABILITY CLASS F

  PLUME PENETRATION ABOVE MIXING HEIGHT OPTION: NINPEN=0
     0  STANDARD TREATMENT OF PLUME PENETRATION ABOVE THE MIXING HEIGHT
     1  NEW SCHEMES FOR PLUME PENETRATION OF ELEVATED STABLE LAYER USED
          FOR STABILITY CLASSES A-D AND BUOYANCY-DOMINATED PLUME

  OUTPUT OPTIONS SELECTED:

     NPRINT=1  LIST OF POINT SOURCE PARAMETERS AND EFFECTIVE STACK HEIGHTS
                 PRINTED AT BEGINNING OF EACH SCENARIO

     FINAL EFFECTIVE PLUME RISE USED: NGPR =1
     BOUYANCY INDUCED DISPERSION FOR NBID=1: NBID = 0
```

```
                                  POLLUTION EPISODIC MODEL (PEM-2)

                OUTPUT:  PEM-2 EXAMPLE 2B: 2 POINT SOURCES, STANDARD PLUME RISE & PENETRATION SCHEMES

        SCENARIO 1    POINT SOURCE PLUME RISE CALCULATIONS
                       MIXING HEIGHT: HMIX= 550.00 M

                                                                                        WIND SPEED AT   MAXIMUM
            SOURCE        EMISSION RATES                                                               
 POINT    COORDINATES   POL-1     POL-2    HEIGHT  DIAMETER   EXIT VEL  EXIT TEMP  DOMINANT  STACK HEIGHT  EFFECTIVE
SOURCE X(KM)    Y(KM)   (G/S)     (G/S)     (M)      (M)       (M/S)    (DEG K)   INFLUENCE    (M/S)     SOURCE HT (M)

   1   30.00     2.00  1000.00    50.00  200.00    5.000      10.000    723.15  BUOYANCY      5.202        454.32
   2   10.00     2.00   500.00    25.00  200.00    4.000       8.000    673.15  BUOYANCY      5.202        364.82
```

```
PEM-2 OUTPUT: SECTION 1 OF 1, SCENARIO 1 PEM-2 EXAMPLE 2B: 2 POINT SOURCES, STANDARD PLUME RISE & PENETRATION SCHEMES
STABILITY=D , WIND SPD= 2.46 M/S, WIND DIR=180.00 DEG, MIXING HT= 550.0 M, AVERAGING TIME= 1 HR.     POLLUTANT-1: SO2
UNCALIBRATED CONCENTRATION - MICROGRAMS PER CUBIC METER
             0.0      4.00      8.00     12.00     16.00     20.00     24.00     28.00     32.00     36.00     40.00     44.00     48.00

   48.00      0    0    0    2   14   28   14    2    0    0    0    0    0    3   27   56   27    3    0    0    0    0    0    0    0
   46.00      0    0    0    1   14   29   14    1    0    0    0    0    0    3   27   58   27    3    0    0    0    0    0    0    0
   44.00      0    0    0    1   14   30   14    1    0    0    0    0    0    3   27   60   27    3    0    0    0    0    0    0    0
   42.00      0    0    0    1   14   31   14    1    0    0    0    0    0    2   27   62   27    2    0    0    0    0    0    0    0
   40.00      0    0    0    1   14   33   14    1    0    0    0    0    0    2   27   65   27    2    0    0    0    0    0    0    0
   38.00      0    0    0    1   13   34   13    1    0    0    0    0    0    2   27   68   27    2    0    0    0    0    0    0    0
   36.00      0    0    0    1   13   35   13    1    0    0    0    0    0    1   26   71   26    1    0    0    0    0    0    0    0
   34.00      0    0    0    1   13   37   13    1    0    0    0    0    0    1   26   74   26    1    0    0    0    0    0    0    0
   32.00      0    0    0    0   13   39   13    0    0    0    0    0    0    1   25   78   25    1    0    0    0    0    0    0    0
   30.00      0    0    0    0   12   41   12    0    0    0    0    0    0    1   24   82   24    1    0    0    0    0    0    0    0
   28.00      0    0    0    0   12   43   12    0    0    0    0    0    0    0   23   87   23    0    0    0    0    0    0    0    0
   26.00      0    0    0    0   11   46   11    0    0    0    0    0    0    0   22   92   22    0    0    0    0    0    0    0    0
   24.00      0    0    0    0   10   49   10    0    0    0    0    0    0    0   20   98   20    0    0    0    0    0    0    0    0
   22.00      0    0    0    0    9   53    9    0    0    0    0    0    0    0   18  105   18    0    0    0    0    0    0    0    0
   20.00      0    0    0    0    8   57    8    0    0    0    0    0    0    0   16  113   16    0    0    0    0    0    0    0    0
   18.00      0    0    0    0    6   61    6    0    0    0    0    0    0    0   13  123   13    0    0    0    0    0    0    0    0
   16.00      0    0    0    0    5   67    5    0    0    0    0    0    0    0   10  135   10    0    0    0    0    0    0    0    0
   14.00      0    0    0    0    3   75    3    0    0    0    0    0    0    0    6  150    6    0    0    0    0    0    0    0    0
   12.00      0    0    0    0    2   85    2    0    0    0    0    0    0    0    3  170    3    0    0    0    0    0    0    0    0
   10.00      0    0    0    0    1   99    1    0    0    0    0    0    0    0    1  198    1    0    0    0    0    0    0    0    0
    8.00      0    0    0    0    0  121    0    0    0    0    0    0    0    0    0  241    0    0    0    0    0    0    0    0    0
    6.00      0    0    0    0    0  142    0    0    0    0    0    0    0    0    0  244    0    0    0    0    0    0    0    0    0
    4.00      0    0    0    0    0  143    0    0    0    0    0    0    0    0    0  136    0    0    0    0    0    0    0    0    0
    2.00      0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
     0.0      0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0

             0.0      4.00      8.00     12.00     16.00     20.00     24.00     28.00     32.00     36.00     40.00     44.00     48.00
```

```
PEM-2 OUTPUT: SECTION 1 OF 1, SCENARIO 1 PEM-2 EXAMPLE 2B: 2 POINT SOURCES, STANDARD PLUME RISE & PENETRATION SCHEMES
STABILITY=D , WIND SPD= 2.46 M/S, WIND DIR=180.00 DEG, MIXING HT=  550.0 M, AVERAGING TIME= 1 HR.  POLLUTANT-1: SO2
UNCALIBRATED SURFACE DEPOSITION FLUX - KILOGRAMS PER SQUARE KILOMETER PER HOUR
          0.0      4.00      8.00     12.00     16.00     20.00     24.00     28.00     32.00     36.00     40.00     44.00     48.00

  48.00    0    0    0    0    1    2    1    0    0    0    0    0    0    0    2    4    2    0    0    0    0    0    0    0    0
  46.00    0    0    0    0    1    2    1    0    0    0    0    0    0    0    2    4    2    0    0    0    0    0    0    0    0
  44.00    0    0    0    0    1    2    1    0    0    0    0    0    0    0    2    4    2    0    0    0    0    0    0    0    0
  42.00    0    0    0    0    1    2    1    0    0    0    0    0    0    0    2    4    2    0    0    0    0    0    0    0    0
  40.00    0    0    0    0    1    2    1    0    0    0    0    0    0    0    2    5    2    0    0    0    0    0    0    0    0
  38.00    0    0    0    0    1    2    1    0    0    0    0    0    0    0    2    5    2    0    0    0    0    0    0    0    0
  36.00    0    0    0    0    1    3    1    0    0    0    0    0    0    0    2    5    2    0    0    0    0    0    0    0    0
  34.00    0    0    0    0    1    3    1    0    0    0    0    0    0    0    2    5    2    0    0    0    0    0    0    0    0
  32.00    0    0    0    0    1    3    1    0    0    0    0    0    0    0    2    6    2    0    0    0    0    0    0    0    0
  30.00    0    0    0    0    1    3    1    0    0    0    0    0    0    0    2    6    2    0    0    0    0    0    0    0    0
  28.00    0    0    0    0    1    3    1    0    0    0    0    0    0    0    2    6    2    0    0    0    0    0    0    0    0
  26.00    0    0    0    0    1    3    1    0    0    0    0    0    0    0    2    7    2    0    0    0    0    0    0    0    0
  24.00    0    0    0    0    1    4    1    0    0    0    0    0    0    0    1    7    1    0    0    0    0    0    0    0    0
  22.00    0    0    0    0    1    4    1    0    0    0    0    0    0    0    1    8    1    0    0    0    0    0    0    0    0
  20.00    0    0    0    0    1    4    1    0    0    0    0    0    0    0    1    8    1    0    0    0    0    0    0    0    0
  18.00    0    0    0    0    0    4    0    0    0    0    0    0    0    0    1    9    1    0    0    0    0    0    0    0    0
  16.00    0    0    0    0    0    5    0    0    0    0    0    0    0    0    1   10    1    0    0    0    0    0    0    0    0
  14.00    0    0    0    0    0    5    0    0    0    0    0    0    0    0    0   11    0    0    0    0    0    0    0    0    0
  12.00    0    0    0    0    0    6    0    0    0    0    0    0    0    0    0   12    0    0    0    0    0    0    0    0    0
  10.00    0    0    0    0    0    7    0    0    0    0    0    0    0    0    0   14    0    0    0    0    0    0    0    0    0
   8.00    0    0    0    0    0    9    0    0    0    0    0    0    0    0    0   17    0    0    0    0    0    0    0    0    0
   6.00    0    0    0    0    0   10    0    0    0    0    0    0    0    0    0   18    0    0    0    0    0    0    0    0    0
   4.00    0    0    0    0    0   10    0    0    0    0    0    0    0    0    0   10    0    0    0    0    0    0    0    0    0
   2.00    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
    0.0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0

          0.0      4.00      8.00     12.00     16.00     20.00     24.00     28.00     32.00     36.00     40.00     44.00     48.00
```

```
PEM-2 OUTPUT: SECTION 1 OF 1, SCENARIO 1 PEM-2 EXAMPLE 2B: 2 POINT SOURCES, STANDARD PLUME RISE & PENETRATION SCHEMES
STABILITY=D, WIND SPD= 2.46 M/S, WIND DIR=180.00 DEG, MIXING HT= 550.0 M, AVERAGING TIME= 1 HR. POLLUTANT-2: SULFATE
UNCALIBRATED CONCENTRATION - MICROGRAMS PER CUBIC METER
          0.0      4.00      8.00     12.00     16.00     20.00     24.00     28.00     32.00     36.00     40.00     44.00     48.00

   48.00    0    0    0    1    7   14    7    1    0    0    0    0    0    2   14   28   14    2    0    0    0    0    0    0    0
   46.00    0    0    0    1    7   14    7    1    0    0    0    0    0    1   13   28   13    1    0    0    0    0    0    0    0
   44.00    0    0    0    1    6   14    6    1    0    0    0    0    0    1   12   27   12    1    0    0    0    0    0    0    0
   42.00    0    0    0    0    6   14    6    0    0    0    0    0    0    1   12   27   12    1    0    0    0    0    0    0    0
   40.00    0    0    0    0    6   13    6    0    0    0    0    0    0    1   11   27   11    1    0    0    0    0    0    0    0
   38.00    0    0    0    0    5   13    5    0    0    0    0    0    0    1   11   27   11    1    0    0    0    0    0    0    0
   36.00    0    0    0    0    5   13    5    0    0    0    0    0    0    1   10   26   10    1    0    0    0    0    0    0    0
   34.00    0    0    0    0    5   13    5    0    0    0    0    0    0    0    9   26    9    0    0    0    0    0    0    0    0
   32.00    0    0    0    0    4   13    4    0    0    0    0    0    0    0    8   26    8    0    0    0    0    0    0    0    0
   30.00    0    0    0    0    4   13    4    0    0    0    0    0    0    0    8   26    8    0    0    0    0    0    0    0    0
   28.00    0    0    0    0    3   13    3    0    0    0    0    0    0    0    7   25    7    0    0    0    0    0    0    0    0
   26.00    0    0    0    0    3   13    3    0    0    0    0    0    0    0    6   25    6    0    0    0    0    0    0    0    0
   24.00    0    0    0    0    3   12    3    0    0    0    0    0    0    0    5   25    5    0    0    0    0    0    0    0    0
   22.00    0    0    0    0    2   12    2    0    0    0    0    0    0    0    4   24    4    0    0    0    0    0    0    0    0
   20.00    0    0    0    0    2   12    2    0    0    0    0    0    0    0    3   24    3    0    0    0    0    0    0    0    0
   18.00    0    0    0    0    1   12    1    0    0    0    0    0    0    0    3   24    3    0    0    0    0    0    0    0    0
   16.00    0    0    0    0    1   12    1    0    0    0    0    0    0    0    2   24    2    0    0    0    0    0    0    0    0
   14.00    0    0    0    0    1   12    1    0    0    0    0    0    0    0    1   24    1    0    0    0    0    0    0    0    0
   12.00    0    0    0    0    0   12    0    0    0    0    0    0    0    0    0   24    0    0    0    0    0    0    0    0    0
   10.00    0    0    0    0    0   12    0    0    0    0    0    0    0    0    0   24    0    0    0    0    0    0    0    0    0
    8.00    0    0    0    0    0   13    0    0    0    0    0    0    0    0    0   25    0    0    0    0    0    0    0    0    0
    6.00    0    0    0    0    0   12    0    0    0    0    0    0    0    0    0   21    0    0    0    0    0    0    0    0    0
    4.00    0    0    0    0    0   10    0    0    0    0    0    0    0    0    0    9    0    0    0    0    0    0    0    0    0
    2.00    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
    0.0     0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0

          0.0      4.00      8.00     12.00     16.00     20.00     24.00     28.00     32.00     36.00     40.00     44.00     48.00
```

```
PEM-2 OUTPUT: SECTION 1 OF 1, SCENARIO 1 PEM-2 EXAMPLE 2B: 2 POINT SOURCES, STANDARD PLUME RISE & PENETRATION SCHEMES
STABILITY=D, WIND SPD= 2.46 M/S, WIND DIR=180.00 DEG, MIXING HT= 550.0 M, AVERAGING TIME= 1 HR. POLLUTANT-2: SULFATE
UNCALIBRATED SURFACE DEPOSITION FLUX - MICROGRAMS PER SQUARE METER PER HOUR
             0.0      4.00      8.00     12.00     16.00     20.00     24.00     28.00     32.00     36.00     40.00     44.00     48.00

  48.00        0    0    0   14  123  251  123   14    0    0    0    0    1   29  246  503  246   29    1    0    0    0    0    0    0
  46.00        0    0    0   12  118  249  118   12    0    0    0    0    1   25  235  499  235   25    1    0    0    0    0    0    0
  44.00        0    0    0   11  112  247  112   11    0    0    0    0    0   21  225  494  225   21    0    0    0    0    0    0    0
  42.00        0    0    0    9  107  245  107    9    0    0    0    0    0   18  214  490  214   18    0    0    0    0    0    0    0
  40.00        0    0    0    7  101  243  101    7    0    0    0    0    0   15  202  486  202   15    0    0    0    0    0    0    0
  38.00        0    0    0    6   95  241   95    6    0    0    0    0    0   12  190  481  190   12    0    0    0    0    0    0    0
  36.00        0    0    0    5   89  238   89    5    0    0    0    0    0    9  178  476  178    9    0    0    0    0    0    0    0
  34.00        0    0    0    3   82  236   82    3    0    0    0    0    0    7  165  472  165    7    0    0    0    0    0    0    0
  32.00        0    0    0    3   75  233   75    3    0    0    0    0    0    5  151  467  151    5    0    0    0    0    0    0    0
  30.00        0    0    0    2   68  231   68    2    0    0    0    0    0    4  137  461  137    4    0    0    0    0    0    0    0
  28.00        0    0    0    1   61  228   61    1    0    0    0    0    0    2  122  456  122    2    0    0    0    0    0    0    0
  26.00        0    0    0    1   54  225   54    1    0    0    0    0    0    1  107  451  107    1    0    0    0    0    0    0    0
  24.00        0    0    0    0   46  223   46    0    0    0    0    0    0    1   92  446   92    1    0    0    0    0    0    0    0
  22.00        0    0    0    0   38  220   38    0    0    0    0    0    0    0   76  440   76    0    0    0    0    0    0    0    0
  20.00        0    0    0    0   30  218   30    0    0    0    0    0    0    0   60  436   60    0    0    0    0    0    0    0    0
  18.00        0    0    0    0   23  216   23    0    0    0    0    0    0    0   45  431   45    0    0    0    0    0    0    0    0
  16.00        0    0    0    0   15  214   15    0    0    0    0    0    0    0   31  428   31    0    0    0    0    0    0    0    0
  14.00        0    0    0    0    9  213    9    0    0    0    0    0    0    0   18  426   18    0    0    0    0    0    0    0    0
  12.00        0    0    0    0    4  213    4    0    0    0    0    0    0    0    9  427    9    0    0    0    0    0    0    0    0
  10.00        0    0    0    0    1  217    1    0    0    0    0    0    0    0    3  433    3    0    0    0    0    0    0    0    0
   8.00        0    0    0    0    0  226    0    0    0    0    0    0    0    0    0  452    0    0    0    0    0    0    0    0    0
   6.00        0    0    0    0    0  223    0    0    0    0    0    0    0    0    0  384    0    0    0    0    0    0    0    0    0
   4.00        0    0    0    0    0  176    0    0    0    0    0    0    0    0    0  167    0    0    0    0    0    0    0    0    0
   2.00        0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
    0.0        0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0

             0.0      4.00      8.00     12.00     16.00     20.00     24.00     28.00     32.00     36.00     40.00     44.00     48.00
```

```
                              POLLUTION EPISODIC MODEL (PEM-2)

              OUTPUT:  PEM-2 EXAMPLE 2B: 2 POINT SOURCES, STANDARD PLUME RISE & PENETRATION SCHEMES

     HIGHEST PREDICTED CONCENTRATION OF EACH POLLUTANT FOR EACH SCENARIO OR AVERAGING PERIOD

     UNCALIBRATED CONCENTRATION IN MICROGRAMS PER CUBIC METER  -  CALIBRATION, POLLUTANT-1:
                                                                   CALIBRATION, POLLUTANT-2:


                             POLLUTANT-1: SO2                                        POLLUTANT-2: SULFATE

 SCENARIO  WIND DIRECTION   COORDINATES           CONCENTRATION           COORDINATES       CONCENTRATION
  NUMBER    SUB-SCENARIO   X(KM)     Y(KM)   UNCALIBRATED    CALIBRATED   X(KM)     Y(KM)  UNCALIBRATED  CALIBRATED

    1                      30.00      6.00     244.1823          0.0      30.00     48.00     27.9226        0.0
```

```
                        POLLUTION EPISODIC MODEL (PEM-2)

        OUTPUT:  PEM-2 EXAMPLE 2B: 2 POINT SOURCES, STANDARD PLUME RISE & PENETRATION SCHEMES

    HIGHEST PREDICTED SURFACE DEPOSITION FLUX OF EACH POLLUTANT FOR EACH SCENARIO OR AVERAGING PERIOD

      UNCALIBRATED VALUES IN MICROGRAMS PER SQUARE METER PER HOUR  -  CALIBRATION, POLLUTANT-1:
                                                                     CALIBRATION, POLLUTANT-2:


                              POLLUTANT-1: SO2                                 POLLUTANT-2: SULFATE

SCENARIO  WIND DIRECTION    COORDINATES     SURFACE DEPOSITION FLUX     COORDINATES     SURFACE DEPOSITION FLUX
 NUMBER    SUB-SCENARIO   X(KM)     Y(KM)  UNCALIBRATED    CALIBRATED  X(KM)     Y(KM)  UNCALIBRATED  CALIBRATED


    1                     30.00      6.00  17581.1211          0.0     30.00     48.00     502.6060         0.0
```

TABLE E-7

INPUT DATA FOR EXAMPLE PROBLEM 3

CARD IMAGES

```
CONTROL CARDS
1  TITLE   PEM-2 EXAMPLE 3: 1 AREA SOURCE & 3 POINT SOURCES, 6-HR AVG CONCENTRATIONS
2  OPTIONS    3   0   0   1   6   0   2   0   0   1   1   0   0   1   0   1   1   0
3  GRID            0.          0.         25         25         1.5      0.015      0.030
4  POLLUTANTS  2    1          2.         0.         0.2        0.        5.0        1.5
5  SCALING         0.          1.         1.         0.         0.        0.         0.
6  LABELS   SO2                                         SULFATE
7  WIND PROFILE 15.    10.    200.     1.    0.20   0.20   0.25   0.30   0.35   0.35
SCENARIO CARDS
                    5                  3.5      260.       5.      200.        0.
                    5                  3.5      260.       5.      200.        0.
                    5                  3.0      270.       1.      200.        0.
                    6                  3.0      270.       1.      150.        0.
                    6                  2.5      280.      -3.      150.        0.
                    6                  2.5      280.      -3.      150.        0.
AREA SOURCE CARDS
                       0.75     15.75    4500.        75.       7.5
               (A BLANK CARD TO SIGNAL END OF AREA SOURCE INVENTORY)
POINT SOURCE CARDS
                    3.0     18.0     100.      15.      30.       2.      4.    250. STACK 1
                    1.5      7.5     200.      10.      50.       3.      5.    200. STACK 2
                    1.5     28.5      60.       6.      10.       1.      2.    150. STACK 3
               (A BLANK CARD TO SIGNAL END OF POINT SOURCE INVENTORY)
```

TABLE E-8

OUTPUT LISTING FOR EXAMPLE PROBLEM 3

PEM-2   (VERSION 84130)

POLLUTION EPISODIC MODEL

INCLUDING
DEPOSITION, SEDIMENTATION, AND CHEMICAL TRANSFORMATION
OF POLLUTANTS

```
                              POLLUTION EPISODIC MODEL (PEM-2)

   INPUT CONTROL PARAMETERS:  PEM-2 EXAMPLE 3: 1 AREA SOURCE & 3 POINT SOURCES, 6-HR AVG CONCENTRATIONS

AVERAGING TIME OPTION: NTOPT=3

       A SCENARIO IS A SET OF METEOROLOGICAL DATA FOR ONE HOUR

   1  1 HOUR: CONCENTRATIONS ARE CALCULATED FOR EACH SCENARIO
   2  24 HOURS: CONCENTRATIONS CALCULATED FOR 24 SCENARIOS ARE AVERAGED
   3  VARIABLE: CONCENTRATIONS CALCULATED FOR A GIVEN NUMBER (2 TO 23) OF SCENARIOS ARE AVERAGED

WIND DIRECTION OPTION: NWDOPT=0

   0  DIRECTION IN DEGREES TO BE SPECIFIED FOR EACH SCENARIO
   1  SECTOR NUMBER TO BE SPECIFIED FOR EACH SCENARIO
  2-7 DIRECTION IN DEGREES TO BE SPECIFIED FOR THE FIRST OF FOUR SUB-SCENARIOS.
       FOR EACH SUCCEEDING SUB-SCENARIO, WIND DIRECTION IS AUTOMATICALLY INCREASED
       BY 90,45,30,15,10,OR 5 DEGREES, DEPENDING ON THE OPTION NUMBER SELECTED.

WIND SPEED OPTION: NWSOPT=0

   0  SPEED IN M/S TO BE SPECIFIED FOR EACH SCENARIO
   1  WIND SPEED CLASS NUMBER TO BE SPECIFIED FOR EACH SCENARIO

NUMBER OF SCENARIOS: NSCEN= 6

RECEPTOR GRID:      COLUMNS: LX= 25    ROWS: LY= 25
                    SPACING: GRID=  1.500 KM
                    SOUTHWEST CORNER    XRSWC=    0.0   KM W
                                        YRSWC=    0.0   KM S
```

```
                                   POLLUTION EPISODIC MODEL (PEM-2)

     INPUT CONTROL PARAMETERS:  PEM-2 EXAMPLE 3: 1 AREA SOURCE & 3 POINT SOURCES, 6-HR AVG CONCENTRATIONS

    NUMBER OF POLLUTANTS: NPOL=2
                                         POLLUTANT-1: SO2                  POLLUTANT-2: SULFATE

  AREA SOURCE SCALING FACTOR:               ASCALE=    1.000                  ASCALE=    1.000

  CALIBRATION COEFFICIENTS:              A=      0.0    B=      0.0        A=      0.0    B=      0.0

  CALIBRATION IDENTIFICATION:

  DEPOSITION VELOCITY (CM/S):                   VD1=   2.000                    VD2=   0.200

  SETTLING VELOCITY (CM/S):                      W1=   0.0                       W2=   0.0

  CHEMICAL TRANSFORMATION OPTION: ICT=1

     NPOL=2
       ICT=0  CHEMICAL TRANSFORMATION LOSS OF POLLUTANTS IS IGNORED
       ICT=1  FIRST-ORDER CHEMICAL TRANSFORMATION OF POLLUTANT-1 TO POLLUTANT-2 IS CONSIDERED

  CHEMICAL TRANSFORMATION OR DECAY RATE: XKT=  5.000 PERCENT/HR

  RATIO OF MOLECULAR WEIGHTS OF POLLUTANT-2 (PRODUCT) TO POLLUTANT-1 (REACTANT): GAMMA= 1.500

  OUTPUT OPTIONS SELECTED:

     NARRAY=2  MAPS OF CONCENTRATION AND SURFACE DEPOSITION FLUX AT EACH RECEPTOR IN THE GRID,
                 UNCALIBRATED ONLY
     NMAX=1    LIST OF RECEPTORS WITH HIGHEST CONCENTRATION AND SURFACE DEPOSITION FLUX
                 FOR EACH SCENARIO - PRINTED AT END OF RUN
```

```
                         POLLUTION EPISODIC MODEL (PEM-2)

INPUT SCENARIO PARAMETERS:  PEM-2 EXAMPLE 3: 1 AREA SOURCE & 3 POINT SOURCES, 6-HR AVG CONCENTRATIONS

                 WIND DIRECTIONS                          WIND SPEED CLASSES           STABILITY CLASSES

SECTOR     DIRECTION     SECTOR    DIRECTION           CLASS   SPEED    CLASS               CLASS
NUMBER         (DEG)     NUMBER        (DEG)           INDEX   (M/S)   INTERVAL(KT)         INDEX    CLASS

   1    N       0.0         9    S     180.0
   2    NNE    22.5        10    SSW   202.5             1      1.50      0-3                  1        A
   3    NE     45.0        11    SW    225.0             2      2.46      4-6                  2        B
   4    ENE    67.5        12    WSW   247.5             3      4.47       7-10                3        C
   5    E      90.0        13    W     270.0             4      6.93     11-16                 4        D
   6    ESE   112.5        14    WNW   292.5             5      9.61     17-21                 5        E
   7    SE    135.0        15    NW    315.0             6     12.52    OVER 21                6        F
   8    SSE   157.5        16    NNW   337.5


SCENARIO  STABILITY  WIND SPEED    WIND     WIND       WIND       AMBIENT    TEMP GRADIENT ABOVE  MIXING
 NUMBER     CLASS      CLASS       SPEED   SECTOR   DIRECTION  TEMPERATURE     MIXING HEIGHT      HEIGHT
                                   (M/S)              (DEG)       (DEG C)         (DEG/M)            (M)

   1          E                    3.500              260.00        5.00                          200.0
   2          E                    3.500              260.00        5.00                          200.0
   3          E                    3.000              270.00        1.00                          200.0
   4          F                    3.000              270.00        1.00                          150.0
   5          F                    2.500              280.00       -3.00                          150.0
   6          F                    2.500              280.00       -3.00                          150.0
```

```
                                   POLLUTION EPISODIC MODEL (PEM-2)

   INPUT AREA SOURCE PARAMETERS:  PEM-2 EXAMPLE 3: 1 AREA SOURCE & 3 POINT SOURCES, 6-HR AVG CONCENTRATIONS

                                                           POLLUTANT-1              POLLUTANT-2
AREA SOURCE     COORDINATES       LENGTH OF SIDE          EMISSION RATE            EMISSION RATE
  NUMBER      X(KM)    Y(KM)           (M)            INPUT (G/S)   SCALED     INPUT (G/S)   SCALED

    1          0.75    15.75         4500.00            75.000      75.000        7.500       7.500

            SUMS OF THE AREA SOURCE EMISSION RATES       75.000      75.000        7.500       7.500

           EFFECTIVE HEIGHT OF THE AREA SOURCE EMISSIONS =   0.0  M
```

```
                                  POLLUTION EPISODIC MODEL (PEM-2)

   INPUT POINT SOURCE PARAMETERS:  PEM-2 EXAMPLE 3: 1 AREA SOURCE & 3 POINT SOURCES, 6-HR AVG CONCERTRATIONS

  POINT SOURCE       COORDINATES       EMISSION RATE        EMISSION RATE      HEIGHT  DIAMETER  EXIT VEL    EXIT TP
 NUMBER    LABEL    X(KM)     Y(KM)   POLLUTANT-1 (G/S)  POLLUTANT-2 (G/S)   (M)      (M)      (M/S)     (DEG )
    1     STACK 1   3.00     18.00        100.000              15.000        30.00    2.000      4.000     250.0
    2     STACK 2   1.50      7.50        200.000              10.000        50.00    3.000      5.000     200.0
    3     STACK 3   1.50     28.50         60.000               6.000        10.00    1.000      2.000     150.0

  SUMS OF THE POINT SOURCE EMISSION RATES    360.000 G/S          31.000 G/S

   INPUT CONTROL PARAMETERS:

    WIND PROFILE EXPONENTS OPTION: NWPOPT=1
       0  EXPONENTS AND ANEMOMETER HEIGHT ARE STANDARD DEFAULT VALUES
       1  EXPONENTS AND ANEMOMETER HEIGHT TO BE SPECIFIED BY THE USER

          USER SPECIFIED WIND PROFILE EXPONENT VALUES:
              0.20   0.20   0.25   0.30   0.35   0.35
              ANEMOMETER HEIGHT = 15.0 METERS  HMIN = 10.0 ,HMAX = 200. ,UMIN = 1.0

    STACK-TIP DOWNWASH ALGORITHM OPTION: NSTDWN=1
       0  ALGORITHM IS IN EFFECT
       1  ALGORITHM IS NOT USED

    NEW PLUME-RISE EQUATIONS OPTION: NPRISE=0
       0  STANDARD PLUME-RISE EQS. ARE USED FOR ALL STABILITY CLASSES
       1  NEW EQS. ARE USED FOR PEAK BUOYANCY RISE FOR STABILITY CLASSES A-D

    POTENTIAL TEMPERATURE GRADIENT: DTDZ(1)=   0.015 DEG/M    STABILITY CLASS E
                                    DTDZ(2)=   0.030 DEG/M    STABILITY CLASS F

    PLUME PENETRATION ABOVE MIXING HEIGHT OPTION: NINPEN=0
       0  STANDARD TREATMENT OF PLUME PENETRATION ABOVE THE MIXING HEIGHT
       1  NEW SCHEMES FOR PLUME PENETRATION OF ELEVATED STABLE LAYER USED
            FOR STABILITY CLASSES A-D AND BUOYANCY-DOMINATED PLUME

    FINAL EFFECTIVE PLUME RISE USED: NGPR=1
    BOUYANCY INDUCED DISPERSION FOR NBID=1: NBID= 0
 PEM-2 OUTPUT: SECTION 1 OF 1  PEM-2 EXAMPLE 3: 1 AREA SOURCE & 3 POINT SOURCES, 6-HR AVG CONCENTRATIONS
6 SCENARIOS,  AVERAGING TIME=  6 HRS.                                               POLLUTANT-1: SO2
UNCALIBRATED CONCENTRATION - MICROGRAMS PER CUBIC METER
               0.0      3.00      6.00      9.00     12.00     15.00     18.00     21.00     24.00     27.00     30.00     33.00     36.00

 36.00          0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    1    1    2
 34.50          0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    1    2    3    4    5    5    5    5
 33.00          0    0    0    0    0    0    0    0    0    0    0    0    1    2    3    5    6    7    7    6    5    4    3    2    2
 31.50          0    0    0    0    0    0    0    0    1    4    7    9   10    9    7    5    4    2    1    1    1    0    0    0    0
 30.00          0    0    0    0    2   12   19   17   12    8    5    3    2    2    2    2    2    2    2    2    2    2    2    2    2
 28.50          0    0  233   76   44   32   27   23   20   18   16   14   13   12   11   11   10    9    9    8    8    7    7    7    7
 27.00          0    0    0    0    4   19   30   27   19   12    7    4    3    2    2    2    2    2    2    2    2    2    2    2    2
 25.50          0    0    0    0    0    0    0    0    2    6   11   15   16   14   11    8    6    4    2    1    1    1    1    1    2
 24.00          0    0    0    0    0    0    0    0    0    0    0    0    1    3    5    7   10   11   11   12   11   11   11   11   10
 22.50          0    0    0    0    0    0    0    0    0    1    1    1    0    1    2    5    7   10   12   14   14   14   14   12   11
 21.00          0    0    0    0    2    4    5    4    4    5    7   11   13   14   13   10    8    5    4    2    2    1    2    2    3
 19.50          0   79   98  108   33   21   26   33   30   23   15    8    4    3    2    2    2    2    2    3    3    3    3    3    3
 18.00          0   79   98  283  120   78   59   49   42   35   28   23   20   18   17   16   15   14   13   13   12   12   11   11   10
 16.50          0   79   98  108   33   23   37   49   45   34   21   12    6    4    3    2    2    2    2    3    3    3    3    3    3
 15.00          0    0    0    0    3    4    6    5    4    6   11   17   21   22   20   17   12    8    5    4    2    2    3    4    6
 13.50          0    0    0    0    0    0    0    0    0    1    1    1    0    1    4    7   12   16   19   22   23   24   23   22   19
 12.00          0    0    0    0    0    0    0    0    0    0    0    0    2    4    8   12   16   19   20   20   20   19   18   17   16
 10.50          0    0    0    0    0    0    0    1    3    9   17   23   25   23   19   14   10    6    4    2    2    1    1    2    3
  9.00          0    0    0    0    5   26   42   40   29   19   12    7    5    4    4    4    4    5    5    5    5    5    5    6    6
  7.50          0    0  150  125   94   74   62   53   47   42   39   36   33   31   29   27   26   25   23   22   21   20   20   19   18
  6.00          0    0    0    0    8   45   71   67   48   30   18   11    7    5    4    4    4    5    5    5    5    5    5    6    6
  4.50          0    0    0    0    0    0    0    1    5   16   29   38   41   38   30   22   15   10    6    4    2    1    1    1    0
  3.00          0    0    0    0    0    0    0    0    0    0    0    1    3    7   13   20   26   29   29   26   22   18   13    9    6
  1.50          0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    1    3    6   10   15   19   21   23   22
  0.0           0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    1    2    3    5    8

               0.0      3.00      6.00      9.00     12.00     15.00     18.00     21.00     24.00     27.00     30.00     33.00     36.00
  PEM-2 OUTPUT: SECTION 1 OF 1  PEM-2 EXAMPLE 3: 1 AREA SOURCE & 3 POINT SOURCES, 6-HR AVG CONCENTRATIONS
 6 SCENARIOS,  AVERAGING TIME=  6 HRS.                                                     POLLUTANT-1: SO2
 UNCALIBRATED SURFACE DEPOSITION FLUX - KILOGRAMS PER SQUARE KILOMETER PER HOUR
          0.0      3.00      6.00      9.00     12.00     15.00     18.00     21.00     24.00     27.00     30.00     33.00     36.00

  36.00    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
  34.50    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
  33.00    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    1    1    0    0    0    0    0    0
  31.50    0    0    0    0    0    0    0    0    0    0    0    1    1    1    1    0    0    0    0    0    0    0    0    0    0
  30.00    0    0    0    0    0    1    1    1    1    1    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
  28.50    0    0   17    5    3    2    2    2    1    1    1    1    1    1    1    1    1    1    1    1    1    1    1    0    0
  27.00    0    0    0    0    0    1    2    2    1    1    1    0    0    0    0    0    0    0    0    0    0    0    0    0    0
  25.50    0    0    0    0    0    0    0    0    0    0    1    1    1    1    1    1    0    0    0    0    0    0    0    0    0
  24.00    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    1    1    1    1    1    1    1    1    1    1
  22.50    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    1    1    1    1    1    1    1    1    1
  21.00    0    0    0    0    0    0    0    0    0    0    1    1    1    1    1    1    1    0    0    0    0    0    0    0    0
  19.50    0    6    7    8    2    1    2    2    2    2    1    1    0    0    0    0    0    0    0    0    0    0    0    0    0
  18.00    0    6    7   20    9    6    4    4    3    2    2    2    1    1    1    1    1    1    1    1    1    1    1    1    1
  16.50    0    6    7    8    2    2    3    4    3    2    2    1    0    0    0    0    0    0    0    0    0    0    0    0    0
  15.00    0    0    0    0    0    0    0    0    0    0    1    1    2    2    1    1    1    1    0    0    0    0    0    0    0
  13.50    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    1    1    1    1    2    2    2    2    2    1
  12.00    0    0    0    0    0    0    0    0    0    0    0    0    0    0    1    1    1    1    1    1    1    1    1    1    1
  10.50    0    0    0    0    0    0    0    0    0    1    1    2    2    2    1    1    1    0    0    0    0    0    0    0    0
   9.00    0    0    0    0    0    2    3    3    2    1    1    1    0    0    0    0    0    0    0    0    0    0    0    0    0
   7.50    0    0   11    9    7    5    4    4    3    3    3    3    2    2    2    2    2    2    2    2    2    1    1    1    1
   6.00    0    0    0    0    1    3    5    5    3    2    1    1    1    0    0    0    0    0    0    0    0    0    0    0    0
   4.50    0    0    0    0    0    0    0    0    0    1    2    3    3    3    2    2    1    1    0    0    0    0    0    0    0
   3.00    0    0    0    0    0    0    0    0    0    0    0    0    0    0    1    1    2    2    2    2    2    1    1    1    0
   1.50    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    1    1    1    2    2    2
    0.0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    1

          0.0      3.00      6.00      9.00     12.00     15.00     18.00     21.00     24.00     27.00     30.00     33.00     36.00
```

```
PEM-2 OUTPUT: SECTION 1 OF 1  PEM-2 EXAMPLE 3: 1 AREA SOURCE & 3 POINT SOURCES, 6-HR AVG CONCENTRATIONS
6 SCENARIOS,  AVERAGING TIME=  6 HRS.                                             POLLUTANT-2: SULFATE
UNCALIBRATED CONCENTRATION - MICROGRAMS PER CUBIC METER
            0.0      3.00      6.00      9.00     12.00     15.00     18.00     21.00     24.00     27.00     30.00     33.00     36.00

 36.00        0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    1    1
 34.50        0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    1    1    2    2    3    3    3
 33.00        0    0    0    0    0    0    0    0    0    0    0    0    0    1    1    2    2    3    3    3    3    2    2    1    1
 31.50        0    0    0    0    0    0    0    0    0    1    2    3    3    3    3    2    1    1    1    0    0    0    0    0    0
 30.00        0    0    0    0    0    2    4    4    3    2    1    1    1    1    1    1    1    1    1    1    1    1    1    1    1
 28.50        0    0   34   13    8    7    6    6    5    5    5    5    5    5    5    4    4    4    4    4    4    4    3    3    3
 27.00        0    0    0    0    1    4    8    8    6    4    3    2    1    1    1    1    1    1    1    1    1    1    1    1    1
 25.50        0    0    0    0    0    0    0    0    1    2    4    6    7    6    5    4    3    2    1    1    0    0    0    1    1
 24.00        0    0    0    0    0    0    0    0    0    0    0    0    0    1    2    4    5    6    7    7    7    6    6    6    5
 22.50        0    0    0    0    0    0    0    0    0    0    0    0    0    0    1    2    3    4    5    6    7    8    8    8    7
 21.00        0    0    0    0    0    1    1    1    1    1    2    3    4    4    4    4    3    2    1    1    1    1    1    2    2
 19.50        0   10   13   15    6    4    6    8    8    7    4    3    1    1    1    1    1    1    1    1    1    1    1    2    2
 18.00        0   10   13   46   24   17   14   13   12   10    9    7    7    6    6    6    6    6    6    6    5    5    5    5    5
 16.50        0   10   13   15    6    5   10   14   14   11    7    4    2    1    1    1    1    1    1    1    1    1    1    2    2
 15.00        0    0    0    0    1    1    2    2    2    2    4    6    8    9    8    7    5    4    3    2    1    1    1    1    1
 13.50        0    0    0    0    0    0    0    0    0    0    0    0    0    1    2    3    5    7    8    9    9    9    8    8    7
 12.00        0    0    0    0    0    0    0    0    0    0    0    0    0    1    1    2    3    4    4    5    6    7    8    8    8
 10.50        0    0    0    0    0    0    0    0    0    1    2    3    4    4    3    2    2    1    1    1    0    0    1    1    2
  9.00        0    0    0    0    0    2    4    4    3    2    1    1    1    1    1    1    1    1    1    1    1    1    1    2    2
  7.50        0    0    9    9    8    7    6    6    6    6    5    5    5    5    5    5    5    5    5    5    5    5    5    5    5
  6.00        0    0    0    0    1    5    8    8    7    5    3    2    1    1    1    1    1    1    1    1    1    1    1    2    2
  4.50        0    0    0    0    0    0    0    0    1    2    5    7    8    8    6    5    4    3    2    1    1    0    0    0    0
  3.00        0    0    0    0    0    0    0    0    0    0    0    0    1    1    3    5    6    7    8    7    6    5    4    3    2
  1.50        0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    1    2    3    4    6    7    7    8
  0.0         0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    1    2    3

            0.0      3.00      6.00      9.00     12.00     15.00     18.00     21.00     24.00     27.00     30.00     33.00     36.00
```

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PEM-2 OUTPUT:  SECTION 1 OF 1   PEM-2 EXAMPLE 3: 1 AREA SOURCE & 3 POINT SOURCES, 6-HR AVG CONCENTRATIONS
6 SCENARIOS,  AVERAGING TIME=  6 HRS.                                              POLLUTANT-2: SULFATE
UNCALIBRATED SURFACE DEPOSITION FLUX - MICROGRAMS PER SQUARE METER PER HOUR
               0.0       3.00      6.00      9.00     12.00     15.00     18.00     21.00     24.00     27.00     30.00     33.00     36.00

  36.00        0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    1    1    3    5    8
  34.50        0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    1    2    5    8   12   16   19   21   21
  33.00        0    0    0    0    0    0    0    0    0    0    0    0    2    4    8   13   18   21   22   21   18   15   12    9    6
  31.50        0    0    0    0    0    0    0    0    2    8   15   21   24   23   19   15   11    7    5    3    2    1    1    1    0
  30.00        0    0    0    0    3   16   28   28   22   15   10    7    5    5    4    5    5    6    6    7    7    8    8    9    9
  28.50        0    0  242   92   59   48   43   40   38   37   35   35   34   33   33   32   32   31   31   31   30   30   30   30   30
  27.00        0    0    0    0    5   32   55   56   43   29   18   12    8    6    5    5    5    6    6    7    7    8    8    9    9
  25.50        0    0    0    0    0    0    0    1    5   15   30   42   48   46   39   30   22   15   10    6    4    3    3    4    7
  24.00        0    0    0    0    0    0    0    0    0    0    0    1    3    8   17   27   37   44   47   48   47   46   44   41   38
  22.50        0    0    0    0    0    0    0    0    0    2    2    2    1    2    6   12   20   28   37   45   51   56   57   56   53
  21.00        0    0    0    0    3    6    9    8    8   11   15   23   29   32   31   26   20   14   10    7    5    5    7   11   17
  19.50        0   73   94  108   42   32   43   59   57   47   31   19    9    7    6    6    6    7    7    8    9    9   10   11   12
  18.00        0   73   94  335  171  124  104   93   85   75   63   52   47   46   44   43   42   41   41   40   40   39   39   38   38
  16.50        0   73   94  108   43   38   70  101   99   80   53   31   16   10    8    7    7    7    8    8    9    9   10   11   12
  15.00        0    0    0    0    5    9   13   12   12   17   28   44   57   64   61   51   39   28   19   13    8    6    6    8   11
  13.50        0    0    0    0    0    0    0    0    0    3    3    4    1    4   11   22   36   50   60   66   68   66   61   55   47
  12.00        0    0    0    0    0    0    0    0    0    0    0    0    2    5    9   15   21   27   32   37   43   49   55   59   60
  10.50        0    0    0    0    0    0    0    0    3    8   16   23   26   26   22   17   12    8    6    4    3    3    4    8   13
   9.00        0    0    0    0    3   17   29   30   23   16   11    7    6    5    5    6    6    7    8    8    9   10   10   11   12
   7.50        0    0   67   67   57   50   46   43   41   40   39   39   38   38   38   37   37   37   37   37   37   37   37   37   37
   6.00        0    0    0    0    6   34   59   61   48   33   21   13    9    7    6    6    6    7    8    8    9   10   10   11   12
   4.50        0    0    0    0    0    0    0    1    5   17   34   49   56   54   46   36   26   18   12    7    5    3    2    1    1
   3.00        0    0    0    0    0    0    0    0    0    0    0    1    4   10   20   32   44   52   55   52   46   38   30   22   16
   1.50        0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    1    2    6   12   21   31   41   49   53   54
   0.0         0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    1    3    7   13   20

               0.0       3.00      6.00      9.00     12.00     15.00     18.00     21.00     24.00     27.00     30.00     33.00     36.00
```

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                              POLLUTION EPISODIC MODEL (PEM-2)

               OUTPUT:  PEM-2 EXAMPLE 3: 1 AREA SOURCE & 3 POINT SOURCES, 6-HR AVG CONCENTRATIONS

HIGHEST PREDICTED CONCENTRATION OF EACH POLLUTANT FOR EACH SCENARIO OR AVERAGING PERIOD

UNCALIBRATED CONCENTRATION IN MICROGRAMS PER CUBIC METER  -  CALIBRATION, POLLUTANT-1:
                                                             CALIBRATION, POLLUTANT-2:


                          POLLUTANT-1: SO2                                       POLLUTANT-2: SULFATE

SCENARIO  WIND DIRECTION  COORDINATES          CONCENTRATION             COORDINATES       CONCENTRATION
 NUMBER    SUB-SCENARIO  X(KM)     Y(KM)   UNCALIBRATED    CALIBRATED   X(KM)     Y(KM)  UNCALIBRATED  CALIBRATED

   1                      4.50     18.00      282.9429        0.0        4.50     18.00     46.4973        0.0
```

```
                        POLLUTION EPISODIC MODEL (PEM-2)

         OUTPUT:  PEM-2 EXAMPLE 3: 1 AREA SOURCE & 3 POINT SOURCES, 6-HR AVG CONCERTRATIONS

HIGHEST PREDICTED SURFACE DEPOSITION FLUX OF EACH POLLUTANT FOR EACH SCENARIO OR AVERAGING PERIOD

UNCALIBRATED VALUES IN MICROGRAMS PER SQUARE METER PER HOUR  -  CALIBRATION, POLLUTANT-1:
                                                                CALIBRATION, POLLUTANT-2:

                                POLLUTANT-1: SO2                                       POLLUTANT-2: SULFATE

SCENARIO  WIND DIRECTION    COORDINATES     SURFACE DEPOSITION FLUX      COORDINATES    SURFACE DEPOSITION FLUX
 NUMBER    SUB-SCENARIO   X(KM)    Y(KM)   UNCALIBRATED   CALIBRATED   X(KM)    Y(KM)  UNCALIBRATED  CALIBRATED

   1                      4.50     18.00   20371.8892        0.0       4.50     18.00   334.7804         0.0
```

APPENDIX F

PEM-2 FORTRAN LISTING

The PEM-2 (Version 84130) computer program was developed and tested on an IBM computer at the Oak Ridge National Laboratory. The program was later modified slightly to run on a UNIVAC 1100 computer at Research Triangle Park. A listing of the UNIVAC-compatible FORTRAN program follows. The PEM-2 code is also contained on UNAMAP Version 6 magnetic tape available through the National Technical Information Service. The code listing printed herein should be used as the reference.

```
C
C
C                   PEM-2.0  (DATED 86016)
C                   AN AIR QUALITY DISPERSION MODEL IN
C                   SECTION 2. NON-GUIDELINE MODELS
C                   IN UNAMAP (VERSION 6) JULY 86.
C                   SOURCE:  UNAMAP FILE ON EPA'S UNIVAC AT RTP, NC.
C                                                                       PMT00010
C                                                                       PMT00020
C                                                                       PMT00030
C               *** PEM-2   (VERSION  84130) ***                        PMT00040
C                                                                       PMT00050
C                                                                       PMT00060
C                  POLLUTION EPISODIC MODEL                             PMT00070
C                         INCLUDING                                     PMT00080
C   DEPOSITION, SEDIMENTATION, AND CHEMICAL TRANSFORMATION              PMT00090
C                       OF POLLUTANTS                                   PMT00100
C                                                                       PMT00110
C                                                                       PMT00120
C *** PEM-2 PROGRAM DEVELOPMENT : --- MAY 1984                          PMT00130
C                                                                       PMT00140
C     K. SHANKAR RAO                                                    PMT00150
C     ATMOSPHERIC TURBULENCE AND DIFFUSION DIVISION   (ATDD)            PMT00160
C     NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION (NOAA)            PMT00170
C     U.S. DEPARTMENT OF COMMERCE                                       PMT00180
C     P.O. BOX - E                                                      PMT00190
C     OAK RIDGE, TENN 37831                                             PMT00200
C                                                                       PMT00210
C     PHONE: (615) 576-1238                                             PMT00220
C             FTS: 626-1238                                             PMT00230
C                                                                       PMT00240
C     ( THIS WORK WAS DONE UNDER AN INTERAGENCY AGREEMENT               PMT00250
C     BETWEEN THE ENVIRONMENTAL PROTECTION AGENCY AND THE              PMT00260
C     NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION )                 PMT00270
C                                                                       PMT00280
C                                                                       PMT00290
C *** EXTENDED ABSTRACT : PEM-2 (VERSION 84130).                        PMT00300
C                                                                       PMT00310
C        THE POLLUTION EPISODIC MODEL (PEM) DESCRIBED BY RAO AND STEVENSPMT00320
C     (1982) IS AN URBAN SCALE (UP TO 50 KM DISTANCES) AIR POLLUTION    PMT00330
C     MODEL CAPABLE OF PREDICTING SHORT-TERM (1 TO 24-HOUR) AVERAGE     PMT00340
C     SURFACE CONCENTRATIONS AND DEPOSITION FLUXES OF TWO CHEMICALLY    PMT00350
C     COUPLED GASEOUS OR PARTICULATE POLLUTANTS AT UP TO A MAXIMUM OF   PMT00360
C     2500 GROUND-LEVEL RECEPTORS LOCATED ON A 50X50 SQUARE RECEPTOR    PMT00370
C     GRID. PREDICTIONS ARE BASED ON STEADY-STATE GAUSSIAN PLUME ASSUMP-PMT00380
C     TIONS, BRIGGS' PLUME RISE FORMULATIONS, AND PASQUILL-GIFFORD (PG) PMT00390
C     DISPERSION PARAMETERS.  THE SURFACE CONCENTRATION AND DEPOSITION  PMT00400
C     FLUX ESTIMATES OF TWO INDEPENDENT NONREACTIVE (GASEOUS OR PARTICU-PMT00410
C     LATE) POLLUTANTS OR ONE POLLUTANT WITH FIRST-ORDER CHEMICAL DECAY PMT00420
C     CAN BE OBTAINED AS SPECIAL CASES OF THE MODEL.  UP TO 300 POINT   PMT00430
C     SOURCES AND UP TO 50 AREA SOURCES MAY BE INCLUDED IN THE MODEL    PMT00440
C     INPUTS.  CALCULATIONS ARE PERFORMED FOR EACH HOUR USING THE SPECI-PMT00450
C     FIED METEOROLOGICAL DATA. UP TO 24 DIFFERENT SETS OF HOURLY METEO-PMT00460
C     ROLOGICAL DATA MAY BE SPECIFIED AS INPUTS FOR THE DETERMINATION OFPMT00470
C     AIR QUALITY FOR 24 DISTINCT WEATHER SCENARIOS.  POLLUTANT CONCENT-PMT00480
C     RATIONS AND DEPOSITION FLUXES FOR A 2 TO 24 HOUR AVERAGING PERIOD PMT00490
C     ARE CALCULATED BY AVERAGING THE CORRESPONDING VALUES CALCULATED   PMT00500
C     FOR EACH HOUR IN THE PERIOD.                                      PMT00510
C                                                                       PMT00520
C        PEM IS BASED ON THE TEXAS EPISODIC MODEL (TEM, VERSION 8)      PMT00530
C     DEVELOPED BY THE TEXAS AIR CONTROL BOARD (1979).  TEM-8 USES THE  PMT00540
C     GAUSSIAN PLUME CONCENTRATION ALGORITHMS DEVELOPED FOR NONREACTIVE PMT00550
C     POLLUTANTS AND A PERFECTLY REFLECTING SURFACE. CHEMICAL AND PHYSI-PMT00560
C     CAL DEPLETION PROCESSES ARE THEREFORE IGNORED EXCEPT FOR AN OPTIONPMT00570
C     WHICH ALLOWS A SIMPLE EXPONENTIAL DECAY OF POLLUTANT WITH TRAVEL  PMT00580
C     TIME. THIS METHOD REQUIRES AN ACCURATE ESTIMATE OF THE POLLUTANT'SPMT00590
C     HALF-LIFE.                                                        PMT00600
C                                                                       PMT00610
C        IN CONTRAST, PEM EXPLICITLY ACCOUNTS FOR THE DRY DEPOSITION,   PMT00620
C     GRAVITATIONAL SETTLING, AND A FIRST-ORDER CHEMICAL TRANSFORMATION PMT00630
```

```
C     OR DECAY OF GASEOUS OR PARTICULATE POLLUTANTS (OF ANY SIZE) IN    PMT00640
C     THE CONCENTRATION ALGORITHMS.  THESE ALGORITHMS, BASED ON EXACT   PMT00650
C     SOLUTIONS OF A GRADIENT-TRANSFER (K-THEORY) MODEL, WERE GIVEN BY  PMT00660
C     RAO (1981, 1982) AS ANALYTICAL EXTENSIONS OF THE WIDELY USED      PMT00670
C     GAUSSIAN PLUME DISPERSION ALGORITHMS UNDER VARIOUS ATMOSPHERIC     PMT00680
C     STABILITY AND MIXING CONDITIONS.  THUS, PEM TREATS DEPOSITION,    PMT00690
C     SEDIMENTATION, AND CHEMICAL TRANSFORMATION IN A PHYSICALLY REAL-  PMT00700
C     ISTIC AND STRAIGHTFORWARD MANNER, AND IT IS SUBJECT TO THE SAME   PMT00710
C     BASIC ASSUMPTIONS AND LIMITATIONS ASSOCIATED WITH ALL GAUSSIAN    PMT00720
C     PLUME-TYPE MODELS.  FOR FURTHER DETAILS REGARDING THE GRADIENT-   PMT00730
C     TRANSFER MODEL FORMULATIONS, ANALYTICAL SOLUTIONS, PARAMETERI-    PMT00740
C     ZATIONS, AND THE DEVELOPMENT OF THE ALGORITHMS FOR PEM, THE USER  PMT00750
C     SHOULD CONSULT THE REPORTS BY RAO (1981, 1982).  AN EVALUATION OF PMT00760
C     OF THE PEM USING THE ST.LOUIS/RAPS DATA FOR FIVE POLLUTANT SPECIESPMT00770
C     CAN BE FOUND IN THE REPORT BY PENDERGRASS AND RAO (1983).         PMT00780
C                                                                       PMT00790
C        THE PEM-2 MODEL (RAO, 1984) IS DEVELOPED FROM THE PEM (RAO AND PMT00800
C     STEVENS, 1982) WITH THE FOLLOWING KEY MODIFICATIONS:              PMT00810
C                                                                       PMT00820
C     (1) PEM-2 USES BRIGGS' URBAN DISPERSION PARAMETERS (BASED ON THE  PMT00830
C         ST. LOUIS DIFFUSION DATA OF MCELROY AND POOLER) FOR BOTH POINTPMT00840
C         AND AREA SOURCES, WHEREAS PEM USES THE SAME DISPERSION PARAME-PMT00850
C         AS THE TEM-8.                                                 PMT00860
C     (2) THE NUMBER OF STABILITY CLASSES IN PEM-2 ARE REDUCED TO SIX   PMT00870
C         (FROM SEVEN IN THE PEM).                                      PMT00880
C     (3) FOR BUOYANCY-DOMINATED PLUMES IN UNSTABLE/NEUTRAL ATMOSPHERE, PMT00890
C         BRIGGS' NEW PLUME RISE EQUATIONS AND PLUME PENETRATION (OF AN PMT00900
C         ELEVATED STABLE LAYER) SCHEMES ARE INCLUDED AS OPTIONAL FEATU-PMT00910
C         RES IN PEM-2.                                                 PMT00920
C     (4) AN OPTION IS PROVIDED TO USE SITE-SPECIFIC VALUES FOR THE     PMT00930
C         EXPONENTS OF THE WIND-PROFILE POWER LAW AND ANEMOMETER HEIGHT PMT00940
C         AS INPUTS TO PEM-2.                                           PMT00950
C     (5) CONCENTRATIONS FROM AREA SOURCES ARE COMPUTED BY NUMERICAL IN-PMT00960
C         TEGRATION IN PEM-2, WHILE THEY ARE CALCULATED FROM CONCENTRA- PMT00970
C         TION ALGORITHMS BASED ON MASS BUDGETS OF THE SPECIES IN PEM.  PMT00980
C         THE USER MAY SPECIFY AN EFFECTIVE HEIGHT OF EMISSIONS FOR     PMT00990
C         URBAN AREA SOURCES IN PEM-2, WHEREAS THESE EMISSIONS ARE      PMT01000
C         ASSUMED TO OCCUR ONLY AT GROUND-LEVEL IN PEM.                 PMT01010
C         THE NUMBER OF CALCULATION GRID SQUARES USED FOR EACH AREA     PMT01020
C         SOURCE HAVE BEEN INCREASED TO 9 (IN PEM-2) FROM 5 IN PEM TO   PMT01030
C         INCREASE THE PLUME LENGTH AND IMPROVE THE MODEL PERFORMANCE.  PMT01040
C                                                                       PMT01050
C        BASED ON THE NUMBER OF POLLUTANTS (NPOL=1 OR 2) AND THE CHEMI- PMT01060
C     CAL TRANSFORMATION/DECAY OPTION PARAMETER (ICT=0 OR 1) SPECIFIED  PMT01070
C     IN THE MODEL INPUT, PEM-2 PROGRAM DOES ONE OF THE FOLLOWING:      PMT01080
C                                                                       PMT01090
C     (1) IF NPOL=1 AND ICT=0 OR 1, SURFACE CONCENTRATIONS AND DEPOSI-  PMT01100
C        TION FLUXES OF ONE GASEOUS OR PARTICULATE POLLUTANT, WITH THE  PMT01110
C        GIVEN DEPOSITION AND SETTLING VELOCITIES, VD1 AND W1 RESPECTI- PMT01120
C        VELY, ARE CALCULATED.  IF ICT=1, THEN CHEMICAL DECAY OF POLLU- PMT01130
C        TANT IS ALSO CONSIDERED IF THE DECAY RATE XKT > 0. IS GIVEN    PMT01140
C        IN PERCENT PER HOUR.                                           PMT01150
C                                                                       PMT01160
C     (2) IF NPOL=2 AND ICT=0, SURFACE CONCENTRATIONS AND DEPOSITION    PMT01170
C        FLUXES OF TWO DIFFERENT AND UNCOUPLED GASEOUS OR PARTICULATE   PMT01180
C        POLLUTANT SPECIES WITH THE GIVEN DEPOSITION AND SETTLING VELOC-PMT01190
C        ITIES VD1 AND W1 (FOR SPECIES-1) AND VD2 AND W2 (FOR SPECIES-2)PMT01200
C        RESPECTIVELY, ARE CALCULATED.  EMISSION RATES FOR BOTH SPECIES PMT01210
C        MAY BE DIFFERENT.  CHEMICAL DECAY IS NOT CONSIDERED FOR EITHER PMT01220
C        SPECIES EVEN IF A VALUE OF XKT > 0. IS SPECIFIED.              PMT01230
C                                                                       PMT01240
C     (3) IF NPOL=2 AND ICT=1, THE TWO GASEOUS OR PARTICULATE POLLUTANT PMT01250
C        SPECIES ARE COUPLED THROUGH A FIRST-ORDER CHEMICAL TRANSFORMA- PMT01260
C        TION.  THE SURFACE CONCENTRATIONS AND DEPOSITION FLUXES OF BOTHPMT01270
C        THE PRIMARY POLLUTANT (SPECIES-1 OR REACTANT) AS WELL AS THE   PMT01280
C        SECONDARY POLLUTANT (SPECIES-2 OR REACTION PRODUCT) ARE CALCU- PMT01290
C        LATED.  THE CHEMICAL TRANSFORMATION RATE (XKT > 0.) SHOULD BE  PMT01300
C        GIVEN.  BOTH SPECIES MAY BE GIVEN NON-EQUAL DEPOSITION AND SET-PMT01310
C        TLING VELOCITIES.  A NON-ZERO DIRECT EMISSION RATE FOR THE     PMT01320
C        SECONDARY POLLUTANT FROM  THE POINT AND/OR AREA SOURCES MAY    PMT01330
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C        ALSO BE SPECIFIED AS INPUT FOR THIS CASE.                       PMT01340
C                                                                        PMT01350
C        FOR FURTHER DETAILS REGARDING THE MODIFICATION OF THE PEM TO    PMT01360
C     DEVELOP PEM-2, THE USE OF THE PEM-2 AND ITS I/O OPTIONS, INPUT     PMT01370
C     PARAMETERS AND UNITS, AND EXAMPLE PROBLEMS, THE USER SHOULD        PMT01380
C     CONSULT THE PEM-2 USER'S GUIDE BY RAO (1984).                      PMT01390
C                                                                        PMT01400
C                          *** REFERENCES ***                            PMT01410
C                                                                        PMT01420
C     (1) STAFF OF THE TEXAS AIR CONTROL BOARD, 1979:  USER'S GUIDE :    PMT01430
C         TEXAS EPISODIC MODEL.  TEXAS AIR CONTROL BOARD, PERMITS        PMT01440
C         SECTION, AUSTIN, TEXAS 78723, 215 PP.                          PMT01450
C                                                                        PMT01460
C     (2) PENDERGRASS, W. R., AND K. S. RAO, 1983:  EVALUATION OF THE    PMT01470
C         POLLUTION EPISODIC MODEL USING THE RAPS DATA.                  PMT01480
C         EPA-600/3-84-087, U.S.E.P.A., RESEARCH TRIANGLE PARK, NC;      PMT01490
C         NOAA TECH. MEMO. ERL ARL-128, NOAA-ATDL, OAK RIDGE, TN 37831,  PMT01500
C         47 PP.  ATDL CONTRIBUTION FILE 83/18.                          PMT01510
C                                                                        PMT01520
C     (3) RAO, K. S., 1981:  ANALYTICAL SOLUTIONS OF A GRADIENT-TRANSFERPMT01530
C         MODEL FOR PLUME DEPOSITION AND SEDIMENTATION.                  PMT01540
C         EPA-600/3-82-079, U.S.E.P.A., RESEARCH TRIANGLE PARK, NC;      PMT01550
C         NOAA TECH. MEMO. ERL ARL-109, NOAA-ATDL, OAK RIDGE, TN 37831,  PMT01560
C         75 PP.  ATDL CONTRIBUTION FILE NO. 81/14.                      PMT01570
C                                                                        PMT01580
C     (4) RAO, K. S., 1982:  PLUME CONCENTRATION ALGORITHMS WITH         PMT01590
C         DEPOSITION, SEDIMENTATION, AND CHEMICAL TRANSFORMATION.        PMT01600
C         EPA-600/3-84-042, U.S.E.P.A., RESEARCH TRIANGLE PARK, NC;      PMT01610
C         NOAA TECH. MEMO. ERL ARL-124, NOAA-ATDL, OAK RIDGE, TN 37831,  PMT01620
C         87 PP.  ATDL CONTRIBUTION FILE NO. 82/27.                      PMT01630
C                                                                        PMT01640
C     (5) RAO, K. S., AND M. M. STEVENS, 1982:  POLLUTION EPISODIC       PMT01650
C         MODEL USER'S GUIDE.                                            PMT01660
C         EPA-600/8-84-008, U.S.E.P.A., RESEARCH TRIANGLE PARK, NC;      PMT01670
C         NOAA TECH. MEMO. ERL ARL-125, NOAA-ATDL, OAK RIDGE, TN 37831,  PMT01680
C         186 PP.  ATDL CONTRIBUTION FILE NO. 82/28.                     PMT01690
C                                                                        PMT01700
C     (6) RAO, K. S., 1984:  PEM-2 : POLLUTION EPISODIC MODEL            PMT01710
C         (VERSION 2) USER'S GUIDE.                                      PMT01720
C         EPA-            , U.S.E.P.A., RESEARCH TRIANGLE PARK, NC;      PMT01730
C         NOAA TECH. MEMO. ERL ARL-   , NOAA-ATDL, OAK RIDGE, TN 37831,  PMT01740
C         ATDL CONTRIBUTION FILE NO. 84/1 .                              PMT01750
C                                                                        PMT01760
C                                                                        PMT01770
C     QUESTIONS OR COMMENTS MAY BE REFERRED TO:
C
C         JAMES M. GODOWITCH
C         ATMOSOSPHERIC MODELING BRANCH - M.D. 80
C         U.S. ENVIRONMENTAL PROTECTION AGENCY
C         RESEARCH TRIANGLE PARK, NC 27711
C
C         PHONE: (919) 541-4802
C                  FTS: 629-4802
C
C *** PEM-2 (VERSION 84130) : FORTRAN LISTING.                           PMT01780
C                                                                        PMT01790
C                                                                        PMT01800
C                                                                        PMT01810
C                                                                        PMT01820
C                                                                        PMT01830
C *** COMMON BLOCKS, DIMENSIONS, AND DATA STATEMENTS.                    PMT01840
C                                                                        PMT01850
C                                                                        PMT01860
      COMMON/PEMCOM/CONC(50,50,2),SDF(50,50,2),TT(20),                   PMT01870
     1 XP(300),YP(300),EP(300,2),HP(300),DP(300),VP(300),TP(300),        PMT01880
     2 XA(50),YA(50),EA(50,2),SIZE(50),                                  PMT01890
     3 WD(24),WS(24),TA(24),HMIX(24),DTDZI(24),                          PMT01900
     4 AZ(6),BZ(6),CZ(6),P(6),SCLAB(6),DTDZ(2),SECTAN(16),               PMT01910
     5 XSWC,YSWC,GRID,LX,LY,A(2),B(2),POLNAM(3,2),CALNAM(7,2),           PMT01920
     6 ITA,IRD,IWR,IDSK,D80,D47,D8047,DIST,DELTA,HPRIME,
     7 ESH(2),PEAK,IBUOY,IRISE,IDWN,EFF,XS,UINV,WVEC,
     8 NAS,NPS,INDEX,IGRID,IAV,ISCEN,IWDOPT,IWD,ISC,IPS,
     9 NTOPT,NWDOPT,NWSOPT,NWPOPT,NSCEN,NLIST,NARRAY,NTAPE,NCSOPT,
     * NMAX,NSTDWN,NPRISE,NINPEN,INTER,NPRINT,NGPR,NBID
C
      COMMON/PARM1/NPOL,VD1,W1,VD2,W2
      COMMON/PARM1A/ICT,TAUC,GAMMA
      COMMON/PARM2/ISPEC,UTAUC,Q2Q1,XCT,EXCT
      COMMON/PARM2A/HAS,KSC,AA,BA,CA
      COMMON/PARM3/HC,VDC1,WC1,VDC2,WC2
      COMMON/PARM4/V11,V21,V12,V22,V13
      COMMON/PARM5/D11,D21,D12,D22,D31,D32,D33,D6
      COMMON/PARM6/R11,R21,R12,R22,R13,R23,R31,R41,R32,R42
      COMMON/PARM7/QZC1,QZC2,HGT
      COMMON/PARM7A/HA,P1(6)
      COMMON/BLOCK1/PI,SQPI,SQRT2,A1B,A1C
      COMMON/BLOCK2/AI,BI,EPSABS,EPSREL,LW,NIW
      COMMON/EXPCHK/EXPMAX,EXPMIN,ETAMAX
      COMMON/WND/HMIN,HMAX,UMIN,IUFLG
C
      EXTERNAL FUN3,FUN4,FUN5
      REAL*8 FUN3,FUN4,FUN5,X1A,X2A
      REAL*8 AI,BI,EPSABS,EPSREL,RESULT
C     DIMENSION IW(102)
      DIMENSION PRL(2,2),DWL(4),ANGLIM(6)
      DIMENSION ITABLE(9,10),EPSLIM(10),AY(6)
      DIMENSION XA1(9),XA2(9),RCA1(9),RCA2(9),AUX(25)
      DIMENSION RCA2CH(9),RCA2CT(9,50),QA2QA1(50)
C
      DATA PRL/4HMOME,4HNTUM,4HBUOY,4HANCY/
      DATA DWL/4H    ,4H    ,4HDOWN,4HWASH/
      DATA EPSLIM/.12427,.16511,.24504,.35884,.46373,
     1            .55868,.64350,.69482,.71890,.78540/
      DATA ITABLE/0,0,0,0,0,0,0,0,0, 0,0,0,0,1,1,1,1,1,
     1            0,0,0,1,1,1,1,1,2, 0,0,1,1,1,2,2,2,2,
     2            0,0,1,1,2,2,3,3,3, 0,1,1,2,2,3,3,4,4,
     3            0,1,1,2,3,3,4,5,5, 0,1,2,2,3,4,5,6,6,
     4            0,1,2,3,3,4,5,6,7, 0,1,2,3,4,5,6,7,8/
      DATA ANGLIM/0.750492,0.750492,0.575959,0.436332,
     1 0.314159,0.314159/
      DATA AY/.32,.32,.22,.16,.11,.11/
C
C
      CALL WSTCLK
C
C *** DEFINE PROGRAM CONSTANTS.
C
      PI=3.1415927
      PI2=PI/2.
      SQPI=SQRT(PI)
      SQRT2=SQRT(2.)
      A1B=1000./(SQRT2*SQPI)
      A1C=2.*SQPI
      A1D=SQRT2/SQPI
      AI=0.
      BI=1.
      EPSABS=1.0E-3
      EPSREL=1.0E-3
      LW=800
      NIW=102
C     FOR IBM-3033
C     EXPMAX=174.
C     FOR UNIVAC-1100
      EXPMAX=87.
      EXPMIN=50.
      ETAMAX=SQRT(EXPMAX)
C
      WRITE(IWR,5430)
 5430 FORMAT ('1',21X,'PEM-2.0   (DATED 86016)',/,22X,
     1 'AN AIR QUALITY DISPERSION MODEL IN',/,22X,'SECTION 2. ',
     2 'NON-GUIDELINE MODELS',/,22X,'IN UNAMAP (VERSION 6) ',
     3 'JULY 86.',/,22X,'SOURCE:  UNAMAP FILE ON EPA''S ',
     4 'UNIVAC AT RTP, NC.')
C
      WRITE (IWR,5432)                                                   PMT02590
 5432 FORMAT (///////45X,'PEM-2   (VERSION  84130)'/////                 PMT02600
     1 45X,'POLLUTION EPISODIC MODEL'/////                               PMT02610
     2 52X,'INCLUDING'//                                                 PMT02620
     3 30X,'DEPOSITION, SEDIMENTATION, AND CHEMICAL TRANSFORMATION'//    PMT02630
     4 50X,'OF POLLUTANTS'/)                                             PMT02640
C                                                                        PMT02650
      INDEX=0                                                            PMT02660
C                                                                        PMT02670
C  CALL MODEL INPUT ROUTINE TO READ ALL CONTROL PARAMETERS, GRID         PMT02680
C      INFORMATION, METEOROLOGICAL AND EMISSION DATA, AND POLLUTANT      PMT02690
C      DEPOSITION AND TRANSFORMATION PARAMETERS.                         PMT02700
C                                                                        PMT02710
C      *************                                                     PMT02720
      CALL INMOD                                                         PMT02730
C      *************                                                     PMT02740
C                                                                        PMT02750
      VD136=VD1*36.                                                      PMT02760
      VD236=VD2*36.                                                      PMT02770
C                                                                        PMT02780
C                                                                        PMT02790
C *** DETERMINE VALUE OF PARAMETER ISPEC.                                PMT02800
C      ISPEC IS AN INTERNAL ROUTING PARAMETER USED IN PEM-2              PMT02810
C      TO DETERMINE THE APPROPRIATE CONCENTRATION ALGORITHMS             PMT02820
C      TO BE USED FOR A GIVEN PROBLEM.                                   PMT02830
C      VALUE OF ISPEC  IS BASED ON NUMBER OF POLLUTANTS,                 PMT02840
C      AND CHEMICAL TRANSFORMATION OPTION PARAMETER.                     PMT02850
C                                                                        PMT02860
      IF(NPOL.EQ.2) GO TO 41                                             PMT02870
C      ONLY ONE POLLUTANT SPECIES.  FIRST-ORDER CHEMICAL DECAY CAN BE    PMT02880
C      CONSIDERED BY SPECIFYING ICT = 1 AND XKT > 0.                     PMT02890
      ISPEC=1                                                            PMT02900
      GO TO 43                                                           PMT02910
C                                                                        PMT02920
C      TWO POLLUTANT SPECIES.                                            PMT02930
   41 IF(ICT.EQ.1) GO TO 42                                              PMT02940
C      NO CHEMICAL COUPLING. THE TWO SPECIES ARE INDEPENDENT             PMT02950
C      OF EACH OTHER.  CHEMICAL DECAY IS NOT CONSIDERED FOR              PMT02960
C      EITHER SPECIES.                                                   PMT02970
      ISPEC=2                                                            PMT02980
      GO TO 43                                                           PMT02990
C                                                                        PMT03000
C      CHEMICAL COUPLING EXISTS BETWEEN SPECIES-1 (REACTANT)             PMT03010
C      AND SPECIES-2 (PRODUCT). FIRST-ORDER TRANSFORMATION.              PMT03020
   42 ISPEC=3                                                            PMT03030
   43 CONTINUE                                                           PMT03040
C                                                                        PMT03050
C                                                                        PMT03060
C                                                                        PMT03070
C *** DEFINE TIME-AVERAGING MULTIPLIER CONSTANTS.                        PMT03080
C                                                                        PMT03090
      IF(NTOPT.EQ.1) STCONV = 1.                                         PMT03100
      IF(NTOPT.EQ.2) STCONV= 0.04166667                                  PMT03110
      IF(NTOPT.EQ.3) STCONV= 1.0/FLOAT(NSCEN)                            PMT03120
C                                                                        PMT03130
      INDEX=1                                                            PMT03140
C                                                                        PMT03150
C  CALL INPUT ROUTINE TO BRING IN METEOROLOGICAL DATA FOR ONE SCENARIO   PMT03160
C    (NUMBER OF SCENARIO = ISCEN).                                       PMT03170
C                                                                        PMT03180
C      *************                                                     PMT03190
100   CALL INMOD                                                         PMT03200
C      *************                                                     PMT03210
C                                                                        PMT03220
C  CALCULATE WIND VECTOR (WVEC) FOR SCENARIO. IFLAG IS USED BELOW        PMT03230
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C     (STMT. 275) TO DETERMINE METHOD OF RESTRICTING THE AREA OF THE    PMT03240
C     RECEPTOR GRID AFFECTED BY EACH SOURCE.                            PMT03250
C                                                                       PMT03260
175   IF(NWDOPT.EQ.1) GO TO 200                                         PMT03270
      DO 180 IWD=1,16                                                   PMT03280
      DETA=ABS(WD(ISCEN)-SECTAN(IWD))                                   PMT03290
      IF(DETA.LE.0.19634954) GO TO 205                                  PMT03300
180   CONTINUE                                                          PMT03310
      GO TO 205                                                         PMT03320
200   WD(ISCEN)=SECTAN(IWD)                                             PMT03330
205   IF(IWD.LT.8.OR.IWD.GT.10) GO TO 210                               PMT03340
      IFLAG=1                                                           PMT03350
      GO TO 241                                                         PMT03360
210   IF(IWD.NE.11) GO TO 215                                           PMT03370
      IFLAG=2                                                           PMT03380
      GO TO 241                                                         PMT03390
215   IF(IWD.LT.12.OR.IWD.GT.14) GO TO 220                              PMT03400
      IFLAG=3                                                           PMT03410
      GO TO 241                                                         PMT03420
220   IF(IWD.NE.15) GO TO 225                                           PMT03430
      IFLAG=4                                                           PMT03440
      GO TO 241                                                         PMT03450
225   IF(IWD.LT.16.AND.IWD.GT.2) GO TO 230                              PMT03460
      IFLAG=5                                                           PMT03470
      GO TO 241                                                         PMT03480
230   IF(IWD.NE.3) GO TO 235                                            PMT03490
      IFLAG=6                                                           PMT03500
      GO TO 241                                                         PMT03510
235   IF(IWD.LT.4.OR.IWD.GT.6) GO TO 240                                PMT03520
      IFLAG=7                                                           PMT03530
      GO TO 241                                                         PMT03540
240   IFLAG=8                                                           PMT03550
241   WVEC= WD(ISCEN) + 3.14159265                                      PMT03560
      IF(WVEC.GT.6.2831853) WVEC=WVEC - 6.2831853                       PMT03570
      WDV=4.712388981-WD(ISCEN)                                         PMT03580
      IF(WDV.LT.0.)WDV=WDV+6.283185307                                  PMT03590
      WDPANG=WDV+ANGLIM(ISC)                                            PMT03600
      WDMANG=WDV-ANGLIM(ISC)                                            PMT03610
C                                                                       PMT03620
      AA=AZ(ISC)                                                        PMT03630
      BA=BZ(ISC)                                                        PMT03640
      CA=CZ(ISC)                                                        PMT03650
      KSC=ISC                                                           PMT03660
C                                                                       PMT03670
C                                                                       PMT03680
C   CALL AUTGRD TO CALCULATE RECEPTOR GRID PARAMETERS AUTOMATICALLY.    PMT03690
C      ************                                                     PMT03700
       IF(IGRID.EQ.1) CALL AUTGRD                                       PMT03710
C      ************                                                     PMT03720
C                                                                       PMT03730
C *** INITIALIZATION.                                                   PMT03740
C                                                                       PMT03750
C   INITIALIZE CONCENTRATION AND SURFACE DEPOSITION FLUX ARRAYS         PMT03760
       IF(NTOPT.GT.1.AND.ISCEN.GT.1) GO TO 4                            PMT03770
       DO 2 I=1,LX                                                      PMT03780
       DO 2 J=1,LY                                                      PMT03790
       CONC(I,J,1)=0.                                                   PMT03800
       SDF(I,J,1)=0.                                                    PMT03810
       IF(ISPEC.EQ.1.AND.NCSOPT.EQ.0) GO TO 2                           PMT03820
       CONC(I,J,2)=0.                                                   PMT03830
       SDF(I,J,2)=0.                                                    PMT03840
     2 CONTINUE                                                         PMT03850
C                                                                       PMT03860
C                                                                       PMT03870
C                                                                       PMT03880
     4 VGRID= 1./GRID                                                   PMT03890
       GRIDSQ= GRID*GRID                                                PMT03900
       ELX= LX                                                          PMT03910
       ELY= LY                                                          PMT03920
       XB1= XSWC + 0.5*GRID                                             PMT03930
      XB2= XSWC + (ELX-0.5)*GRID
      YB1= YSWC + 0.5*GRID
      YB2= YSWC + (ELY-0.5)*GRID
C
C
C*** A R E A   S O U R C E   C A L C U L A T I O N S ***
C
C    IF NO AREA SOURCES, SKIP AREA SOURCE CALCULATIONS.
      IF(NAS.LT.1) GO TO 245
C
C    IWV HELPS DETERMINE THE PATTERN OF GRID SQUARES AFFECTED BY EACH
C    AREA SOURCE.  PATTERN DEPENDS ONLY ON WIND DIRECTION.
C    EPS IS THE ANGLE BETWEEN THE WIND VECTOR AND THE NEAREST
C    COORDINATE AXIS.
C
      IWV= 1 + WVEC/0.78540
      GO TO (2411,2412,2413,2414,2415,2416,2417,2418),IWV
 2411 ITABX=1
      ISIGNX=1
      ISIGNY=1
      EPS= WVEC
      GO TO 2419
 2412 ITABX=0
      ISIGNX=1
      ISIGNY=1
      EPS= 1.5708 - WVEC
      GO TO 2419
 2413 ITABX=0
      ISIGNX=1
      ISIGNY=-1
      EPS= WVEC - 1.57080
      GO TO 2419
 2414 ITABX=1
      ISIGNX=1
      ISIGNY=-1
      EPS= 3.1416 - WVEC
      GO TO 2419
 2415 ITABX=1
      ISIGNX=-1
      ISIGNY=-1
      EPS= WVEC - 3.1416
      GO TO 2419
 2416 ITABX=0
      ISIGNX=-1
      ISIGNY=-1
      EPS= 4.7124 - WVEC
      GO TO 2419
 2417 ITABX=0
      ISIGNX=-1
      ISIGNY=1
      EPS= WVEC - 4.7124
      GO TO 2419
 2418 ITABX=1
      ISIGNX=-1
      ISIGNY=1
      EPS= 6.2832 - WVEC
 2419 IF(ITABX.EQ.0) GO TO 2420
      ITABY=0
      INCRX=0
      INCRY=1
      GO TO 2421
 2420 ITABY=1
      INCRX=1
      INCRY=0
 2421 DO 2422 L=1,10
      IF(EPS.GT.EPSLIM(L)) GO TO 2422
      IEPS=L
      GO TO 2423
 2422 CONTINUE
      IEPS=10
```

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C                                                                       PMT04640
 2423 DXA=1000.*GRID/COS(EPS)                                           PMT04650
      IF(NWPOPT.EQ.1) THEN                                              PMT04660
C   OPTIONAL WIND PROFILE EXPONENTS USED                                PMT04670
      CALL WIND(WS(ISCEN),P1(ISC),HAS,UPL)                              PMT04680
      ELSE                                                              PMT04690
C    DEFAULT URBAN WIND PROFILE EXPONENTS USED                          PMT04700
      CALL WIND(WS(ISCEN),P(ISC),HAS,UPL)                               PMT04710
      END IF                                                            PMT04720
      UINV=1./UPL                                                       PMT04730
      UPL=1./UINV                                                       PMT04740
      UINV1=UINV/100.                                                   PMT04750
C                                                                       PMT04760
C     DEFINE NONDIMENSIONAL DEPOSITION AND SEDIMENTATION PARAMETERS.    PMT04770
C                                                                       PMT04780
C     ISPEC = 1 OR 2 OR 3                                               PMT04790
      VDC1=VD1*UINV1                                                    PMT04800
      WC1=W1*UINV1                                                      PMT04810
      V11=VDC1-0.5*WC1                                                  PMT04820
      V21=VDC1-WC1                                                      PMT04830
      IF(ISPEC.EQ.1) GO TO 46                                           PMT04840
C                                                                       PMT04850
C     ISPEC = 2 OR 3                                                    PMT04860
      VDC2=VD2*UINV1                                                    PMT04870
      WC2=W2*UINV1                                                      PMT04880
      V12=VDC2-0.5*WC2                                                  PMT04890
      V22=VDC2-WC2                                                      PMT04900
      IF(ISPEC.EQ.2) GO TO 47                                           PMT04910
C                                                                       PMT04920
C     ISPEC = 3                                                         PMT04930
      V13=V11-0.5*(WC1-WC2)                                             PMT04940
C                                                                       PMT04950
C     ISPEC = 1 OR 3                                                    PMT04960
   46 UTAUC=TAUC*UPL                                                    PMT04970
   47 CONTINUE                                                          PMT04980
C                                                                       PMT04990
C                                                                       PMT05000
C     CALCULATE RELATIVE CONCENTRATIONS AT A RECEPTOR LOCATED AT THE    PMT05010
C     CENTER OF THE CALCULATION GRID SQUARE CONTAINING THE AREA SOURCE  PMT05020
C     EMISSIONS, AND AT THE CENTER OF EACH OF THE EIGHT GRID SQUARES    PMT05030
C     IMMEDIATELY DOWNWIND OF THE SOURCE.                               PMT05040
C                                                                       PMT05050
      NDIM=15                                                           PMT05060
      EPSAXI=.01                                                        PMT05070
      XA1(1)=1.0                                                        PMT05080
      XA2(1)=0.5*DXA                                                    PMT05090
C                                                                       PMT05100
C     START LOOP ON NINE CALCULATION GRID SQUARES WITH RECEPTORS        PMT05110
      DO 111 I=1,9                                                      PMT05120
      X1A=XA1(I)                                                        PMT05130
      X2A=XA2(I)                                                        PMT05140
C                                                                       PMT05150
C     SPECIES-1 CONCENTRATION  (ISPEC = 1 OR 2 OR 3)                    PMT05160
C     COMPUTE INTEGRAL F3(X1A,X2A); FUN3 IS THE EXTERNALLY              PMT05170
C     DEFINED INTEGRAND FUNCTION.                                       PMT05180
C     ************                                                      PMT05190
      CALL XINTEG(X1A,X2A,EPSAXI,NDIM,FUN3,RESULT,IER1,AUX)             PMT05200
C     ************                                                      PMT05210
      RCA1(I)=A1D*RESULT                                                PMT05220
      IF(ISPEC.EQ.1) GO TO 108                                          PMT05230
C                                                                       PMT05240
C     SPECIES-2 CONCENTRATION                                           PMT05250
C     ISPEC=2 OR ISPEC=3 (DIRECT EMISSION CONTRIBUTION)                 PMT05260
C     COMPUTE INTEGRAL F5(X1A,X2A); FUN5 IS THE EXTERNALLY              PMT05270
C     DEFINED INTEGRAND FUNCTION.                                       PMT05280
C     ************                                                      PMT05290
      CALL XINTEG(X1A,X2A,EPSAXI,NDIM,FUN5,RESULT,IER2,AUX)             PMT05300
C     ************                                                      PMT05310
      RCA2(I)=A1D*RESULT                                                PMT05320
      IF(ISPEC.EQ.2) GO TO 108                                          PMT05330
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C                                                                       PMT05340
C     SPECIES-2 CONCENTRATION                                           PMT05350
C     ISPEC=3 (CHEMICAL TRANSFORMATION CONTRIBUTION)                    PMT05360
C     COMPUTE INTEGRAL F4(X1A,X2A); FUN4 IS THE EXTERNALLY              PMT05370
C     DEFINED INTEGRAND FUNCTION.                                       PMT05380
C     ************                                                      PMT05390
      CALL XINTEG(X1A,X2A,EPSAXI,NDIM,FUN4,RESULT,IER3,AUX)             PMT05400
C     ************                                                      PMT05410
      RCA2CH(I)=A1D*GAMMA*RESULT                                        PMT05420
C                                                                       PMT05430
  108 IF(I.EQ.9) GO TO 111                                              PMT05440
      XA1(I+1)=XA2(I)                                                   PMT05450
      XA2(I+1)=XA1(I+1)+DXA                                             PMT05460
  111 CONTINUE                                                          PMT05470
C     END LOOP ON I=1,9 CALCULATION GRID SQUARES.                       PMT05480
C                                                                       PMT05490
      IF(ISPEC.NE.3) GO TO 114                                          PMT05500
C     START LOOP ON ALL AREA SOURCES IF ISPEC=3                         PMT05510
      DO 114 K=1,NAS                                                    PMT05520
      IF(EA(K,1).LT.1.E-6) EA(K,1)=1.E-6                                PMT05530
      QA2QA1(K)=EA(K,2)/EA(K,1)                                         PMT05540
      DO 113 I=1,9                                                      PMT05550
      RCA2CT(I,K)=QA2QA1(K)*RCA2(I) + RCA2CH(I)                         PMT05560
  113 CONTINUE                                                          PMT05570
  114 CONTINUE                                                          PMT05580
C     END LOOP ON K=1,NAS AREA SOURCES IF ISPEC = 3                     PMT05590
C                                                                       PMT05600
C                                                                       PMT05610
C  LOOP THROUGH ALL AREA SOURCES.  EMISSIONS FROM EACH AREA SOURCE      PMT05620
C    ARE APPORTIONED AMONG THE RECEPTOR GRID SQUARES WHOLLY OR          PMT05630
C    PARTIALLY COVERED BY THE SOURCE.  EACH AFFECTED RECEPTOR GRID      PMT05640
C    SQUARE IS TREATED AS A SOURCE.                                     PMT05650
C                                                                       PMT05660
C     START LOOP ON K=1,NAS AREA SOURCES.                               PMT05670
      DO 2429 K=1,NAS                                                   PMT05680
      AREA= SIZE(K)*SIZE(K)                                             PMT05690
      AX1= XA(K)                                                        PMT05700
      AX2= AX1 + SIZE(K)                                                PMT05710
      NX1= (AX1-XSWC)*VGRID + 9.                                        PMT05720
      NX2= (AX2-XSWC)*VGRID + 9.                                        PMT05730
      IF(NX1.GT.LX+16.OR.NX2.LT.1) GO TO 2429                           PMT05740
      IF(NX1.GE.1) GO TO 32                                             PMT05750
      NX1= 1                                                            PMT05760
      AX1= XSWC - 8.*GRID                                               PMT05770
32    IF(NX2.LE.LX+16) GO TO 34                                         PMT05780
      NX2= LX+16                                                        PMT05790
      AX2= XSWC + (ELX + 8.)*GRID                                       PMT05800
34    X1= XSWC + (FLOAT(NX1)-9.)*GRID                                   PMT05810
      X2= XSWC + (FLOAT(NX2)-8.)*GRID                                   PMT05820
      AY1= YA(K)                                                        PMT05830
      AY2= AY1 + SIZE(K)                                                PMT05840
      NY1= (AY1-YSWC)*VGRID + 9.                                        PMT05850
      NY2= (AY2-YSWC)*VGRID + 9.                                        PMT05860
      IF(NY1.GT.LY+16.OR.NY2.LT.1) GO TO 2429                           PMT05870
      IF(NY1.GE.1) GO TO 36                                             PMT05880
      NY1= 1                                                            PMT05890
      AY1= YSWC - 8.*GRID                                               PMT05900
36    IF(NY2.LE.LY+16) GO TO 38                                         PMT05910
      NY2= LY+16                                                        PMT05920
      AY2= YSWC + (ELY + 8.)*GRID                                       PMT05930
38    Y1= YSWC + (FLOAT(NY1)-9.)*GRID                                   PMT05940
      Y2= YSWC + (FLOAT(NY2)-8.)*GRID                                   PMT05950
C                                                                       PMT05960
C     START LOOP ON IX=NX1,NX2 COLUMNS OF THE RECEPTOR GRID.            PMT05970
      DO 2428 IX=NX1,NX2                                                PMT05980
      IF(NX1.NE.NX2) GO TO 10                                           PMT05990
      DXQ= AX2-AX1                                                      PMT06000
      GO TO 13                                                          PMT06010
10    IF(IX.NE.NX1) GO TO 11                                            PMT06020
      DXQ= GRID+X1-AX1                                                  PMT06030
      GO TO 13
11    IF(IX.NE.NX2) GO TO 12
      DXQ= GRID+AX2-X2
      GO TO 13
12    DXQ=GRID
C
C     START LOOP ON JY=NY1,NY2 ROWS OF THE RECEPTOR GRID.
13    DO 2427 JY=NY1,NY2
      IF(NY1.NE.NY2) GO TO 20
      DY= AY2-AY1
      GO TO 23
20    IF(JY.NE.NY1) GO TO 21
      DY= GRID+Y1-AY1
      GO TO 23
21    IF(JY.NE.NY2) GO TO 22
      DY= GRID+AY2-Y2
      GO TO 23
22    DY=GRID
23    SPLIT= DXQ*DY/(AREA*GRIDSQ)
C
C  LOOP FOR THE NINE RECEPTORS AFFECTED BY EACH RECEPTOR GRID SQUARE
C    CONTAINING EMISSIONS.  THE RECEPTORS IN THE EIGHT DOWNWIND SQUARES
C    AND IN THE SOURCE SQUARE ITSELF ARE AFFECTED.
C
      DO 2426 L=1,9
      NX= IX + ISIGNX*(ITABLE(L,IEPS)*ITABX + (L-1)*INCRX) - 8
      IF(NX.LT.1.OR.NX.GT.LX) GO TO 2426
      NY= JY + ISIGNY*(ITABLE(L,IEPS)*ITABY + (L-1)*INCRY) - 8
      IF(NY.LT.1.OR.NY.GT.LY) GO TO 2426
C
C     CALCULATE GROUND-LEVEL CONCENTRATIONS CONC (MICROGRAMS PER CUBIC
C     METER) AND SURFACE DEPOSITION FLUXES SDF (MICROGRAMS PER SQUARE
C     METER PER HOUR) OF POLLUTANTS AT RECEPTOR IN COLUMN NX, ROW NY
C     OF THE RECEPTOR GRID DUE TO AREA SOURCE K.
C
C     ISPEC = 1 OR 2 OR 3
      CINC1=RCA1(L)*EA(K,1)*SPLIT*STCONV*UINV
      CONC(NX,NY,1)=CONC(NX,NY,1)+CINC1
      SDF(NX,NY,1)=SDF(NX,NY,1)+VD136*CINC1
      IF(ISPEC.EQ.1) GO TO 2426
      IF(ISPEC.EQ.3) GO TO 2425
C
C     ISPEC = 2
      CINC2=RCA2(L)*EA(K,2)*SPLIT*STCONV*UINV
      CONC(NX,NY,2)=CONC(NX,NY,2)+CINC2
      SDF(NX,NY,2)=SDF(NX,NY,2)+VD236*CINC2
      GO TO 2426
C
C     ISPEC = 3
2425  CINC2=RCA2CT(L,K)*EA(K,1)*SPLIT*STCONV*UINV
      CONC(NX,NY,2)=CONC(NX,NY,2)+CINC2
      SDF(NX,NY,2)=SDF(NX,NY,2)+VD236*CINC2
C
2426  CONTINUE
C     END LOOP ON L=1,9 CALCULATION GRID SQUARES WITH RECEPTORS.
C
2427  CONTINUE
C     END LOOP ON JY=NY1,NY2 ROWS OF THE RECEPTOR GRID.
C
2428  CONTINUE
C     END LOOP ON IX=NX1,NX2 COLUMNS OF THE RECEPTOR GRID.
C
2429  CONTINUE
C     END LOOP ON K=1,NAS AREA SOURCES.
C
C
C
C *** POINT SOURCES.
C
C
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C  IF NO POINT SOURCES, SKIP POINT SOURCE CALCULATIONS.
  245 IF(NPS.LT.1) GO TO 603
C
C
C
C***  P O I N T   S O U R C E   C A L C U L A T I O N S  ***
C
C  LOOP THROUGH ALL POINT SOURCES.
      DO 600 I=1,NPS
      IF((NWDOPT.GT.1.AND.IWDOPT.GT.1).OR.NTOPT.EQ.2) GO TO 247
      IF(NPRINT.EQ.0) GO TO 247
      IF((I-1)/50*50.NE.I-1) GO TO 247
      IF(NINPEN.EQ.0) GO TO 246
      IF(ISC.GE.5) GO TO 246
      WRITE(IWR,1001) TT,ISCEN,HMIX(ISCEN),DTDZI(ISCEN)
      WRITE(IWR,1003)
      GO TO 247
  246 WRITE(IWR,1005) TT,ISCEN,HMIX(ISCEN)
      WRITE(IWR,1007)
  247 IPS=I
C     IF PHYSICAL STACK HEIGHT EXCEEDS MIXING HEIGHT, THE SOURCE
C     IS IGNORED.
      IF(HP(I).GE.HMIX(ISCEN)) GO TO 600
      EFF= 2.45*VP(I)*DP(I)*DP(I)*(TP(I)-TA(ISCEN))/TP(I)
      IF(EFF.LT.0.) EFF=1.0E-7
C
C  CALCULATE INVERSE WIND SPEED (UINV) AT THE PHYSICAL HEIGHT (HP(I))
C    OF POINT SOURCE I.  DO NOT CHANGE IF STACK HEIGHT IS LESS
C    THAN 10 METERS.
C
       IF(NWPOPT.EQ.1) THEN
C    USE OPTIONAL POWER LAW EXPONENTS
      CALL WIND(WS(ISCEN),P1(ISC),HP(I),UPL)
      ELSE
C    USE DEFAULT URBAN WIND PROFILE EXPONENTS
      CALL WIND(WS(ISCEN),P(ISC),HP(I),UPL)
      END IF
      UINV=1./UPL
C
C  DEFINE EMISSION RATES (SOURCE STRENGTHS) OF POLLUTANT SPECIES,
C    AND NONDIMENSIONAL DEPOSITION AND SEDIMENTATION PARAMETERS.
      UINV1=UINV/100.
C
C     ISPEC = 1 OR 2 OR 3
      Q1=EP(I,1)
      VDC1=VD1*UINV1
      WC1=W1*UINV1
      V11=VDC1-0.5*WC1
      V21=VDC1-WC1
      IF(V21.EQ.0.) GO TO 251
      R11=V11/V21
      R21=0.5*WC1/V21
  251 IF(ISPEC.EQ.1) GO TO 255
C
C     ISPEC = 2 OR 3
      Q2=EP(I,2)
      VDC2=VD2*UINV1
      WC2=W2*UINV1
      V12=VDC2-0.5*WC2
      V22=VDC2-WC2
      IF(V22.EQ.0.) GO TO 253
      R12=V12/V22
      R22=0.5*WC2/V22
  253 IF(ISPEC.EQ.2) GO TO 257
C
C     ISPEC = 3
      IF(Q1.EQ.0.) Q1=1.E-6
      Q2Q1=Q2/Q1
      V13=V11-0.5*(WC1-WC2)
      IF(V21.EQ.0.) GO TO 255
      R13=V13/V21
      R23=0.5*WC2/V21
C
C     ISPEC = 1 OR 3
  255 UTAUC=TAUC*UPL
  257 KLID=0
C
C
C *** PEAK EFFECTIVE SOURCE HEIGHT CALCULATIONS.
C
C  CALL SUBROUTINE RISE WITH IRISE=2 TO GET PEAK EFFECTIVE SOURCE
C    HEIGHT, ESH(2).
C
      IRISE=2
C     ************
      CALL RISE
C     ************
      IRISE=1
C
C  CALCULATE DISTANCE AT WHICH PLUME REACHES MAXIMUM HEIGHT (PEAK).
C
      IF(IBUOY.EQ.0) GO TO 263
      IF(ISC.LT.5) GO TO 261
      PEAK=0.00207148/(UINV*SQRT(DTDZ(ISC-4)*9.8/TA(ISCEN)))
      GO TO 265
  261 PEAK=0.001*XS
      GO TO 265
  263 PEAK= 0.
      IF(ISC.GE.5) GO TO 265
      IF(ABS(VP(I)).LT..000001) GO TO 265
      PEAK=(0.004*UINV*DP(I)*(VP(I) + 3./UINV)**2)/VP(I)
C
  265 IF(NINPEN.EQ.0) GO TO 264
      IF(ISC.GE.5.OR.IBUOY.EQ.0) GO TO 264
      GO TO 267
C
C  STANDARD TREATMENT OF PLUME PENETRATION ABOVE MIXING HEIGHT:
C      IF MAXIMUM EFFECTIVE SOURCE HEIGHT EXCEEDS THE MIXING HEIGHT,
C      PLUME ESCAPES THE MIXED LAYER, AND SOURCE IS IGNORED.
  264 IF(NPRINT.EQ.0) GO TO 266
      IF(NWDOPT.LE.1.OR.IWDOPT.LE.1) WRITE(IWR,1010)
     1 I,XP(I),YP(I),Q1,Q2,HP(I),DP(I),VP(I),TP(I),PRL(1,IBUOY+1),
     2 PRL(2,IBUOY+1),DWL(IDWN),DWL(IDWN+1),UPL,ESH(2)
  266 IF(ESH(2).GT.HMIX(ISCEN)) GO TO 600
      GO TO 275
C
C  NEW SCHEMES TO ACCOUNT FOR PLUME PENETRATION OF ELEVATED STABLE
C      LAYER FOR UNSTABLE/NEUTRAL ATMOSPHERE & BUOYANCY-DOMINATED PLUME.
  267 PPF=0.
      IPPF=0
      ZIP=HMIX(ISCEN)-HP(I)
C     HPEN IS THE MINIMUM EFFECTIVE PLUME CENTERLINE HEIGHT NECESSAY TO
C     CONSIDER PENETRATION.
      HPEN=HP(I)+2.*ZIP/3.
      IF(ESH(2).LT.HPEN) GO TO 270
C
C     ESTIMATE MAXIMUM PLUME RISE ASSUMING THAT THE MIXED LAYER IS
C     STABLY-STRATIFIED WITH THE SAME POT.TEMP.GRADIENT AS THAT IN THE
C     ELEVATED STABLE LAYER.  THIS IS A SIMPLE, CONSERVATIVE APPROACH
C     SINCE THE ACTUAL PLUME RISE WILL BE GREATER.
      SI=9.8*DTDZI(ISCEN)/TA(ISCEN)
      DELHP=2.6*(EFF*UINV/SI)**0.333333
C
C     CALCULATE PLUME PENETRATION FRACTION (PPF) DEFINED AS THE RATIO
C     OF DEPTH OF PLUME ABOVE THE MIXING HEIGHT, (1.5*DELHP - ZIP),
C     TO THE TOTAL PLUME DEPTH, (DELHP).
      PPF=1.5-ZIP/DELHP
C
C     COMPLETE PENETRATION (PPF=1.): THE ENTIRE PLUME ESCAPES THE MIXED
C     LAYER. IGNORE THIS SOURCE SINCE IT DOES NOT CONTRIBUTE TO THE GLC.
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      IF (PPF.GT.0.999) GO TO 268                                       PMT08120
      GO TO 269                                                         PMT08130
  268 IPPF=1                                                            PMT08140
      PPF=1.                                                            PMT08150
      Q1=0.                                                             PMT08160
      IF(ISPEC.GT.1) Q2=0.                                              PMT08170
      GO TO 270                                                         PMT08180
C                                                                       PMT08190
C     NO PENETRATION (PPF=0.): THE ENTIRE PLUME REMAINS WITHIN THE MIXEDPMT08200
C     LAYER. SET MAXIMUM EFFECTIVE STACK HEIGHT AS EQUAL TO HPEN.       PMT08210
  269 IF(PPF.LT.0.001) PPF=0.                                           PMT08220
C                                                                       PMT08230
C     PARTIAL PENETRATION (0. < PPF < 1.): CALCULATE THE NEW MAXIMUM    PMT08240
C     EFFECTIVE STACK HEIGHT.  THIS IS THE HEIGHT OF CENTERLINE OF THE  PMT08250
C     PLUME FRACTION REMAINING WITHIN THE MIXED LAYER.                  PMT08260
      RATP=(1.-0.5*PPF)/(1.5-PPF)                                       PMT08270
      ESH(2)=HP(I)+ZIP*RATP                                             PMT08280
C                                                                       PMT08290
C     DETERMINE DOWNWIND DISTANCE (PEAK) IN KILOMETERS WHERE THIS       PMT08300
C     MAXIMUM HEIGHT OCCURS.                                            PMT08310
      PEAK=.001*((RATP*ZIP/(1.6*UINV))**1.5)/SQRT(EFF)                  PMT08320
C     REDEFINE THE SOURCE STRENGTH SO THAT ONLY (1.-PPF) FRACTION OF THEPMT08330
C     PLUME MATERIAL REMAINING WITHIN MIXED LAYER CONTRIBUTES TO THE GLCPMT08340
      Q1=(1.-PPF)*Q1                                                    PMT08350
      IF(ISPEC.EQ.1) GO TO 270                                          PMT08360
      Q2=(1.-PPF)*Q2                                                    PMT08370
C                                                                       PMT08380
C     PRINT CALCULATED PLUME RISE PARAMETERS.                           PMT08390
  270 IF(NPRINT.EQ.0) GO TO 271                                         PMT08400
      IF(NWDOPT.LE.1.OR.IWDOPT.LE.1) WRITE(IWR,1012)                    PMT08410
     1 I,XP(I),YP(I),Q1,Q2,HP(I),DP(I),VP(I),TP(I),PRL(1,IBUOY+1),      PMT08420
     2 PRL(2,IBUOY+1),DWL(IDWN),DWL(IDWN+1),UPL,ESH(2),PPF              PMT08430
  271 IF(IPPF.EQ.1) GO TO 600                                           PMT08440
C                                                                       PMT08450
C                                                                       PMT08460
C  SET LIMITS (XMIN,XMAX,YMIN,YMAX) ON PORTION OF RECEPTOR GRID         PMT08470
C    EXAMINED FOR EACH SOURCE. THE EXTENT OF THIS PORTION DEPENDS       PMT08480
C    ON SOURCE LOCATION, GRID DIMENSIONS, AND WIND DIRECTION.           PMT08490
C                                                                       PMT08500
275   XMAX= XB2                                                         PMT08510
      XMIN= XB1                                                         PMT08520
      YMAX= YB2                                                         PMT08530
      YMIN= YB1                                                         PMT08540
      IF(XP(I)+50.0.LT.XB2) XMAX= XP(I) + 50.                           PMT08550
      IF(XP(I)-50.0.GT.XB1) XMIN= XP(I) - 50.                           PMT08560
      IF(YP(I)+50.0.LT.YB2) YMAX= YP(I) + 50.                           PMT08570
      IF(YP(I)-50.0.GT.YB1) YMIN= YP(I) - 50.                           PMT08580
C                                                                       PMT08590
      DO 242 II=1,2                                                     PMT08600
      FANGC=FLOAT(2*(II-1)+1)*PI2                                       PMT08610
      DIF1=ABS(ABS(WDPANG)-FANGC)                                       PMT08620
      DIF2=ABS(ABS(WDMANG)-FANGC)                                       PMT08630
      IF(DIF1.LT..001) WDPANG=WDPANG+.001                               PMT08640
      IF(DIF2.LT..001) WDMANG=WDMANG-.001                               PMT08650
242   CONTINUE                                                          PMT08660
C                                                                       PMT08670
      GO TO (280,285,290,295,300,305,310,315),IFLAG                     PMT08680
280   IF(WDPANG.GT.3.14)GOTO282                                         PMT08690
      IF(WDMANG.LT.0)GOTO284                                            PMT08700
      YMIN=YP(I)                                                        PMT08710
      XL1=XP(I)+(YB2-YP(I))/TAN(WDPANG)                                 PMT08720
      IF(XL1.GT.XMIN)XMIN=XL1                                           PMT08730
      IF(XL1.GT.XP(I))XMIN=XP(I)                                        PMT08740
      XL2=XP(I)+(YB2-YP(I))/TAN(WDMANG)                                 PMT08750
      IF(XL2.LT.XMAX)XMAX=XL2                                           PMT08760
      IF(XL2.LT.XP(I))XMAX=XP(I)                                        PMT08770
      GOTO320                                                           PMT08780
282   YMIN=YP(I)+(XB1-XP(I))*TAN(WDPANG)                                PMT08790
      XMAX=XP(I)+(YB2-YP(I))/TAN(WDMANG)                                PMT08800
      GOTO320                                                           PMT08810
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284   YMIN=YP(I)+(XB2-XP(I))*TAN(WDMANG)                                PMT08820
      XMIN=XP(I)+(YB2-YP(I))/TAN(WDPANG)                                PMT08830
      GOTO320                                                           PMT08840
285   XL1=XP(I)+(YB2-YP(I))/TAN(WDPANG)                                 PMT08850
      IF(XL1.GT.XMIN)XMIN=XL1                                           PMT08860
      IF(XL1.GT.XP(I))XMIN=XP(I)                                        PMT08870
      YL1=YP(I)+(XB2-XP(I))*TAN(WDMANG)                                 PMT08880
      IF(YL1.GT.YMIN)YMIN=YL1                                           PMT08890
      IF(YL1.GT.YP(I))YMIN=YP(I)                                        PMT08900
      GOTO320                                                           PMT08910
290   IF(WDPANG.GT.1.57.AND.WDMANG.LT.0.)GOTO292                        PMT08920
      IF(WDPANG.GT.6.28.AND.WDMANG.LT.4.712)GOTO294                     PMT08930
      XMIN=XP(I)                                                        PMT08940
      YL1=YP(I)+(XB2-XP(I))*TAN(WDMANG)                                 PMT08950
      IF(YL1.GT.YMIN)YMIN=YL1                                           PMT08960
      IF(YL1.GT.YP(I))YMIN=YP(I)                                        PMT08970
      YL2=YP(I)+(XB2-XP(I))*TAN(WDPANG)                                 PMT08980
      IF(YL2.LT.YMAX)YMAX=YL2                                           PMT08990
      IF(YL2.LT.YP(I))YMAX=YP(I)                                        PMT09000
      GOTO320                                                           PMT09010
292   YMIN=YP(I)+(XB2-XP(I))*TAN(WDMANG)                                PMT09020
      XMIN=XP(I)+(YB2-YP(I))/TAN(WDPANG)                                PMT09030
      GOTO320                                                           PMT09040
294   XMIN=XP(I)+(YB1-YP(I))/TAN(WDMANG)                                PMT09050
      YMAX=YP(I)+(XB2-XP(I))*TAN(WDPANG)                                PMT09060
      GOTO320                                                           PMT09070
295   XL1=XP(I)+(YB1-YP(I))/TAN(WDMANG)                                 PMT09080
      IF(XL1.GT.XMIN)XMIN=XL1                                           PMT09090
      IF(XL1.GT.XP(I))XMIN=XP(I)                                        PMT09100
      YL2=YP(I)+(XB2-XP(I))*TAN(WDPANG)                                 PMT09110
      IF(YL2.LT.YMAX)YMAX=YL2                                           PMT09120
      IF(YL2.LT.YP(I))YMAX=YP(I)                                        PMT09130
      GOTO320                                                           PMT09140
300   IF(WDPANG.GT.6.28)GOTO302                                         PMT09150
      IF(WDMANG.LT.3.14)GOTO304                                         PMT09160
      YMAX=YP(I)                                                        PMT09170
      XL1=XP(I)+(YB1-YP(I))/TAN(WDMANG)                                 PMT09180
      IF(XL1.GT.XMIN)XMIN=XL1                                           PMT09190
      IF(XL1.GT.XP(I))XMIN=XP(I)                                        PMT09200
      XL2=XP(I)+(YB1-YP(I))/TAN(WDPANG)                                 PMT09210
      IF(XL2.LT.XMAX)XMAX=XL2                                           PMT09220
      IF(XL2.LT.XP(I))XMAX=XP(I)                                        PMT09230
      GOTO320                                                           PMT09240
302   YMAX=YP(I)+(XB2-XP(I))*TAN(WDPANG)                                PMT09250
      XMIN=XP(I)+(YB1-YP(I))/TAN(WDMANG)                                PMT09260
      GOTO320                                                           PMT09270
304   YMAX=YP(I)+(XB1-XP(I))*TAN(WDMANG)                                PMT09280
      XMAN=XP(I)+(YB1-YP(I))/TAN(WDPANG)                                PMT09290
      GOTO320                                                           PMT09300
305   YL2=YP(I)+(XB1-XP(I))*TAN(WDMANG)                                 PMT09310
      IF(YL2.LT.YMAX)YMAX=YL2                                           PMT09320
      IF(YL2.LT.YP(I))YMAX=YP(I)                                        PMT09330
      XL2=XP(I)+(YB1-YP(I))/TAN(WDPANG)                                 PMT09340
      IF(XL2.LT.XMAX)XMAX=XL2                                           PMT09350
      IF(XL2.LT.XP(I))XMAX=XP(I)                                        PMT09360
      GOTO320                                                           PMT09370
310   IF(WDMANG.LT.1.57)GOTO312                                         PMT09380
      IF(WDPANG.GT.4.712)GOTO314                                        PMT09390
      XMAX=XP(I)                                                        PMT09400
      YL1=YP(I)+(XB1-XP(I))*TAN(WDPANG)                                 PMT09410
      IF(YL1.GT.YMIN)YMIN=YL1                                           PMT09420
      IF(YL1.GT.YP(I))YMIN=YP(I)                                        PMT09430
      YL2=YP(I)+(XB1-XP(I))*TAN(WDMANG)                                 PMT09440
      IF(YL2.LT.YMAX)YMAX=YL2                                           PMT09450
      IF(YL2.LT.YP(I))YMAX=YP(I)                                        PMT09460
      GOTO320                                                           PMT09470
312   XL2=XP(I)+(YB2-YP(I))/TAN(WDMANG)                                 PMT09480
      IF(XL2.LT.XMAX)XMAX=XL2                                           PMT09490
      IF(XL2.LT.XP(I))XMAX=XP(I)                                        PMT09500
      YL1=YP(I)+(XB1-XP(I))*TAN(WDPANG)                                 PMT09510
      IF(YL1.GT.YMIN)YMIN=YL1                                           PMT09520
      IF(YL1.GT.YP(I))YMIN=YP(I)                                        PMT09530
      GOTO320                                                           PMT09540
314   XL2=XP(I)+(YB1-YP(I))/TAN(WDPANG)                                 PMT09550
      IF(XL2.LT.XMAX)XMAX=XL2                                           PMT09560
      IF(XL2.LT.XP(I))XMAX=XP(I)                                        PMT09570
      YL2=YP(I)+(XB1-XP(I))*TAN(WDMANG)                                 PMT09580
      IF(YL2.LT.YMAX)YMAX=YL2                                           PMT09590
      IF(YL2.LT.YP(I))YMAX=YP(I)                                        PMT09600
      GOTO320                                                           PMT09610
315   XL2=XP(I)+(YB2-YP(I))/TAN(WDMANG)                                 PMT09620
      IF(XL2.LT.XMAX)XMAX=XL2                                           PMT09630
      IF(XL2.LT.XP(I))XMAX=XP(I)                                        PMT09640
      YL1=YP(I)+(XB1-XP(I))*TAN(WDPANG)                                 PMT09650
      IF(YL1.GT.YMIN)YMIN=YL1                                           PMT09660
      IF(YL1.GT.YP(I))YMIN=YP(I)                                        PMT09670
      GOTO320                                                           PMT09680
320   IF(XMIN.GT.XB2.OR.XMAX.LT.XB1.OR.YMIN.GT.YB2.OR.YMAX.LT.YB1)      PMT09690
     1 GO TO 600                                                        PMT09700
      IF(XMIN.LT.XB1) XMIN=XB1                                          PMT09710
      IF(XMAX.GT.XB2) XMAX=XB2                                          PMT09720
      IF(YMIN.LT.YB1) YMIN=YB1                                          PMT09730
      IF(YMAX.GT.YB2) YMAX=YB2                                          PMT09740
C                                                                       PMT09750
C  DETERMINE THE RANGE OF RECEPTOR GRID ROW AND COLUMN NUMBERS (LXMAX,  PMT09760
C    LXMIN,LYMAX,LYMIN) CORRESPONDING TO XMAX, ETC. ABOVE -             PMT09770
C                                                                       PMT09780
      LXMAX= (XMAX-XSWC)/GRID + 1.                                      PMT09790
      LXMIN= (XMIN-XSWC)/GRID + 1.                                      PMT09800
      LYMAX= (YMAX-YSWC)/GRID + 1.                                      PMT09810
      LYMIN= (YMIN-YSWC)/GRID + 1.                                      PMT09820
C                                                                       PMT09830
C     START LOOP ON ALL AFFECTED RECEPTORS.                             PMT09840
      DO 500 IX=LXMIN,LXMAX                                             PMT09850
      XI=IX                                                             PMT09860
      XG= XSWC + (XI-0.5)*GRID                                          PMT09870
      XD= XG - XP(I) + 0.00001                                          PMT09880
      XDSQ=XD*XD                                                        PMT09890
      DO 500 JY=LYMIN,LYMAX                                             PMT09900
      YJ=JY                                                             PMT09910
      YG= YSWC + (YJ-0.5)*GRID                                          PMT09920
      YD= YG - YP(I) + 0.00001                                          PMT09930
C  DSQ= SQUARE OF SOURCE-RECEPTOR DISTANCE. IF SOURCE-RECEPTOR DISTANCE PMT09940
C    IS GREATER THAN 50 KM., RECEPTOR IS SKIPPED.                       PMT09950
      DSQ= XDSQ + YD*YD                                                 PMT09960
      IF(DSQ.GT.2500.) GO TO 500                                        PMT09970
      DELTA= ATAN(XD/YD)                                                PMT09980
      IF(DELTA.LT.0.) DELTA = DELTA + 3.1415927                         PMT09990
      IF(XD.LT.0.) DELTA = DELTA + 3.1415927                            PMT10000
      DELTA= ABS(DELTA - WVEC)                                          PMT10010
      IF(DELTA.GT.3.1415927) DELTA= ABS(6.2831853 - DELTA)              PMT10020
      DIF1=ABS(DELTA-PI2)                                               PMT10030
      IF(DIF1.LT..001) DELTA=DELTA+.001                                 PMT10040
C  IF THE CROSSWIND ANGLE (DELTA) EXCEEDS A LIMITING VALUE WHICH        PMT10050
C    DEPENDS ON STABILITY CLASS (ANGLIM), THE RECEPTOR IS SKIPPED.      PMT10060
C      ANGLIM = 43.,43.,33.,25.,18., AND 18. DEGREES FOR 1-HOUR AVERAGE PMT10070
C      FOR STABILITY CLASSES A, B, C, D, E, AND F RESPECTIVELY.         PMT10080
C                                                                       PMT10090
      IF(DELTA.GT.ANGLIM(ISC)) GO TO 500                                PMT10100
C  DELTA IS THE ANGLE BETWEEN THE WIND VECTOR AND THE SOURCE-RECEPTOR   PMT10110
C    DIRECTION.  THE DOWNWIND DISTANCE USED IN THE GAUSSIAN PLUME       PMT10120
C    EQUATION IS=   DIST= SQRT(DSQ)*COS(DELTA).                         PMT10130
      DIST=SQRT(DSQ)*COS(DELTA)                                         PMT10140
      IF(DIST.LT.0.002) GO TO 500                                       PMT10150
C                                                                       PMT10160
C                                                                       PMT10170
C *** DETERMINE PROBABILITY DENSITIES OF VERTICAL DISTRIBUTIONS         PMT10310
C     OF  SPECIES-1 AND SPECIES-2 POLLUTANT CONCENTRATIONS.             PMT10320
C                                                                       PMT10330
      IF(DIST.GT.D47) GO TO 330                                         PMT10340
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C **** NEAR-SOURCE REGION (DIST .LE. D47).                              PMT10350
C      CALCULATE QZC1 AND QZC2 FROM QZCAL (MODULE M=1).                 PMT10360
C      ************                                                     PMT10370
       CALL QZCAL                                                       PMT10380
C      ************                                                     PMT10390
       GO TO 350                                                        PMT10400
C                                                                       PMT10410
  330 IF(DIST.LT.D80) GO TO 331                                         PMT10420
C **** WELL-MIXED REGION (DIST .GE. D80).                               PMT10430
C      CALCULATE QZC1 AND QZC2 FROM QZCAL (MODULE M=2).                 PMT10440
C      ************                                                     PMT10450
       CALL QZCAL                                                       PMT10460
C      ************                                                     PMT10470
       GO TO 350                                                        PMT10480
C                                                                       PMT10490
  331 IF(KLID.EQ.1) GO TO 337                                           PMT10500
C      CALCULATE QZC1 AND QZC2 FOR POLLUTANT SPECIES                    PMT10510
C      AT DIST=D47 AND DIST=D80 FOR USE IN INTERPOLATION                PMT10520
C      IN PLUME-TRAPPING REGION.                                        PMT10530
       DUMX=DIST                                                        PMT10540
       DIST=D47                                                         PMT10550
C      ************                                                     PMT10560
       CALL QZCAL                                                       PMT10570
C      ************                                                     PMT10580
       QZC11=QZC1                                                       PMT10590
       IF(ISPEC.EQ.1) GO TO 332                                         PMT10600
       QZC21=QZC2                                                       PMT10610
C                                                                       PMT10620
  332 DIST=D80                                                          PMT10630
C      ************                                                     PMT10640
       CALL QZCAL                                                       PMT10650
C      ************                                                     PMT10660
       QZC12=QZC1                                                       PMT10670
       IRC1=1                                                           PMT10680
       IF(QZC11.EQ.0.OR.QZC12.EQ.0.) IRC1=0                             PMT10690
       IF(ISPEC.EQ.1) GO TO 333                                         PMT10700
       QZC22=QZC2                                                       PMT10710
       IRC2=1                                                           PMT10720
       IF(QZC21.EQ.0.OR.QZC22.EQ.0.) IRC2=0                             PMT10730
C                                                                       PMT10740
  333 KLID=1                                                            PMT10750
       DIST=DUMX                                                        PMT10760
       IF(IRC1.EQ.0) GO TO 334                                          PMT10770
       DIFX1=ALOG(D80/D47)                                              PMT10780
       DIFC1=ALOG(QZC12/QZC11)                                          PMT10790
       GO TO 335                                                        PMT10800
  334 DIFC1=QZC12-QZC11                                                 PMT10810
  335 IF(ISPEC.EQ.1) GO TO 337                                          PMT10820
       IF(IRC2.EQ.0) GO TO 336                                          PMT10830
       DIFX2=ALOG(D80/D47)                                              PMT10840
       DIFC2=ALOG(QZC22/QZC21)                                          PMT10850
       GO TO 337                                                        PMT10860
  336 DIFC2=QZC22-QZC21                                                 PMT10870
C                                                                       PMT10880
C **** PLUME-TRAPPING REGION (D47 < DIST < D80).                        PMT10890
C      CALCULATE QZC1 AND QZC2 BY LINEAR INTERPOLATION                  PMT10900
C      (BETWEEN VALUES AT DIST=D47 AND DIST=D80) ON                     PMT10910
C      A LOG-LOG PLOT OF QZC VERSUS DOWNWIND DISTANCE.                  PMT10920
C      IF EITHER OF THE QZC VALUES AT D47 AND D80 ARE                   PMT10930
C      ZERO, USE A LINEAR PLOT FOR INTERPOLATION.                       PMT10940
  337 IF(IRC1.EQ.0) GO TO 338                                           PMT10950
       RATX1=ALOG(DIST/D47)/DIFX1                                       PMT10960
       QZC1L=ALOG(QZC11)+RATX1*DIFC1                                    PMT10970
       QZC1=EXP(QZC1L)                                                  PMT10980
       GO TO 339                                                        PMT10990
  338 RATX1=(DIST-D47)/D8047                                            PMT11000
       QZC1=QZC11+RATX1*DIFC1                                           PMT11010
  339 IF(ISPEC.EQ.1) GO TO 350                                          PMT11020
C                                                                       PMT11030
       IF(IRC2.EQ.0) GO TO 340                                          PMT11040
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      RATX2=ALOG(DIST/D47)/DIFX2                                        PMT11050
      QZC2L=ALOG(QZC21)+RATX2*DIFC2                                     PMT11060
      QZC2=EXP(QZC2L)                                                   PMT11070
      GO TO 350                                                         PMT11080
  340 RATX2=(DIST-D47)/D8047                                            PMT11090
      QZC2=QZC21+RATX2*DIFC2                                            PMT11100
C                                                                       PMT11110
C *** DETERMINE PROBABILITY DENSITY OF CROSSWIND DISTRIBUTION           PMT10180
C     OF CONCENTRATIONS.                                                PMT10190
C                                                                       PMT10200
350   XM=DIST*1000.                                                     PMT10210
      SIGY=AY(ISC)*XM/(SQRT(1.+.0004*XM))                               PMT10220
C. CHECK FOR BID OPTION.  OMIT BID IF NBID=0.                           PMT10221
      IF(NBID.EQ.0) GO TO 351                                           PMT10222
C. CONSIDER BOUYANCY INDUCED DISPERSION. DH IS SAME AS DELTAH.          PMT10223
      DH=HGT-HPRIME                                                     PMT10224
      SIGB=DH/3.5                                                       PMT10225
      SIGB=SIGB*SIGB                                                    PMT10225
      SIGY=SQRT(SIGY*SIGY + SIGB)                                       PMT10226
351   YM=XM*TAN(DELTA)                                                  PMT10230
      DUMY=YM/SIGY                                                      PMT10240
      ARG=0.5*DUMY*DUMY                                                 PMT10250
      IF(ARG.GE.EXPMIN) GO TO 500                                       PMT10260
      EXPA=EXP(-ARG)                                                    PMT10270
      PYC=(A1B/SIGY)*EXPA                                               PMT10280
C                                                                       PMT10290
C                                                                       PMT10300
C                                                                       PMT11120
C                                                                       PMT11130
C     CALCULATE GROUND-LEVEL CONCENTRATIONS CONC (MICROGRAMS PER CUBIC  PMT11140
C     METER) AND SURFACE DEPOSITION FLUX SDF (MICROGRAMS PER SQUARE     PMT11150
C     METER PER HOUR) OF POLLUTANTS AT RECEPTOR IN COLUMN IX, ROW JY    PMT11160
C     OF THE RECEPTOR GRID DUE TO POINT SOURCE I.                       PMT11170
C                                                                       PMT11180
C     ISPEC = 1 OR 2 OR 3                                               PMT11190
      C1=Q1*UINV*PYC*QZC1                                               PMT11200
      IF(NCSOPT.EQ.0) GO TO 355                                         PMT11210
      CALL WORST(IX,JY,C1,1)                                            PMT11220
C                                                                       PMT11230
  355 CINC1=C1*STCONV                                                   PMT11240
      CONC(IX,JY,1)=CONC(IX,JY,1)+CINC1                                 PMT11250
      SDF(IX,JY,1)=SDF(IX,JY,1)+VD136*CINC1                             PMT11260
      IF(ISPEC.EQ.1) GO TO 370                                          PMT11270
      IF(ISPEC.EQ.3) GO TO 360                                          PMT11280
C                                                                       PMT11290
C     ISPEC = 2                                                         PMT11300
      C2=Q2*UINV*PYC*QZC2                                               PMT11310
      GO TO 363                                                         PMT11320
C                                                                       PMT11330
C     ISPEC = 3                                                         PMT11340
  360 C2=Q1*UINV*PYC*QZC2                                               PMT11350
C                                                                       PMT11360
  363 IF(NCSOPT.EQ.0) GO TO 365                                         PMT11370
      CALL WORST(IX,JY,C2,2)                                            PMT11380
C                                                                       PMT11390
  365 CINC2=C2*STCONV                                                   PMT11400
      CONC(IX,JY,2)=CONC(IX,JY,2)+CINC2                                 PMT11410
      SDF(IX,JY,2)=SDF(IX,JY,2)+VD236*CINC2                             PMT11420
  370 CONTINUE                                                          PMT11430
C                                                                       PMT11440
500   CONTINUE                                                          PMT11450
C     END LOOP ON ALL AFFECTED RECEPTORS.                               PMT11460
C                                                                       PMT11470
600   CONTINUE                                                          PMT11480
C     END LOOP ON ALL POINT SOURCES.                                    PMT11490
C                                                                       PMT11500
C                                                                       PMT11510
C                                                                       PMT11520
C *** PRINT OUTPUT.                                                     PMT11530
C                                                                       PMT11540
```

```
C     OUTPUT AT END OF EACH AVERAGING-PERIOD.                           PMT11550
C                                                                       PMT11560
C     TIME AVERAGING:  NTOPT=2 OR 3                                     PMT11570
C       IF NOT LAST SCENARIO, GO TO 100 FOR THE NEXT SCENARIO.          PMT11580
C       IF LAST SCENARIO, CALL OUTMOD TO PRINT OUTPUT FOR NLIST, NTAPE, PMT11590
C         AND NARRAY OPTIONS, AND THEN CALL MAXOUT TO PRINT OUTPUT      PMT11600
C         FOR NMAX.                                                     PMT11610
C                                                                       PMT11620
C     OUTPUT AT END OF EACH SCENARIO (OR SUB-SCENARIO)                  PMT11630
C     NO TIME AVERAGING: NTOPT=1                                        PMT11640
C       AT END OF EACH SCENARIO (OR SUB-SCENARIO WHEN NWDOPT.GT.1),     PMT11650
C         CALL OUTMOD TO PRINT OUTPUT FOR NCSOPT, NLIST, NTAPE,         PMT11660
C         AND NARRAY OPTIONS.                                           PMT11670
C       IF LAST SCENARIO (AND LAST SUB-SCENARIO WHEN NWDOPT.GT.1),      PMT11680
C         CALL MAXOUT TO PRINT OUTPUT FOR NMAX OPTION.                  PMT11690
C       IF NOT LAST SCENARIO, GO TO 100 FOR THE THE NEXT SCENARIO       PMT11700
C         OR SUB-SCENARIO.                                              PMT11710
C                                                                       PMT11720
  603 IF(NTOPT.EQ.1) GO TO 620                                          PMT11730
C                                                                       PMT11740
C     TIME AVERAGING: NTOPT=2 OR 3                                      PMT11750
      IF(ISCEN.NE.NSCEN) GO TO 100                                      PMT11760
C     ************                                                      PMT11770
      CALL OUTMOD                                                       PMT11780
C     ************                                                      PMT11790
      GO TO 999                                                         PMT11800
C                                                                       PMT11810
C     NO TIME AVERAGING: NTOPT=1                                        PMT11820
C     ************                                                      PMT11830
  620 CALL OUTMOD                                                       PMT11840
C     ************                                                      PMT11850
      IF(ISCEN.NE.NSCEN) GO TO 100                                      PMT11860
      IF(NWDOPT.LE.1) GO TO 999                                         PMT11870
      IF(IWDOPT.LT.4) GO TO 100                                         PMT11880
C                                                                       PMT11890
C     ************                                                      PMT11900
  999 IF(NMAX.GT.0) CALL MAXOUT                                         PMT11910
C     ************                                                      PMT11920
C                                                                       PMT11930
      CALL WAUDIT
      STOP                                                              PMT11940
C                                                                       PMT11950
C                                                                       PMT11960
 1001 FORMAT(1H1,37X,'POLLUTION EPISODIC MODEL (PEM-2)'///4X,'OUTPUT:  'PMT11970
     1,20A4//4X,'SCENARIO',I2,4X,'POINT SOURCE PLUME RISE CALCULATIONS'/PMT11980
     221X,'MIXING HEIGHT: HMIX=',F7.2,' M'/                             PMT11990
     321X,'POTENTIAL TEMPERATURE GRADIENT ABOVE MIXING HEIGHT=',        PMT12000
     4F6.4,' DEG/M'/)                                                   PMT12010
 1003 FORMAT(11X,'SOURCE',6X,'EMISSION RATES',2X,'STACK',4X,'EXIT',     PMT12020
     15X,'EXIT',4X,'EXIT',17X,'WIND SPEED AT',2X,'MAX.EFF.',6X,'PLUME',/PMT12030
     2' POINT',3X,'COORDINATES',3X,'POL-1',3X,'POL-2',3X,'HEIGHT',      PMT12040
     3' DIAMETER VELOCITY  TEMP.',5X,'DOMINANT',3X,'STACK HEIGHT  SOURCEPMT12050
     4 HT.  PENETRATION'/' SOURCE X(KM)   Y(KM)  (G/S)   (G/S)',4X,     PMT12060
     5'(M)',6X,'(M)',4X,'(M/S)  (DEG K)',4X,'INFLUENCE',7X,'(M/S)',8X,  PMT12070
     6'(M)',7X,'FRACTION'/)                                             PMT12080
 1005 FORMAT(1H1,37X,'POLLUTION EPISODIC MODEL (PEM-2)'//4X,'OUTPUT:  ',PMT12090
     120A4//4X,'SCENARIO',I2,4X,'POINT SOURCE PLUME RISE CALCULATIONS'/ PMT12100
     221X,'MIXING HEIGHT: HMIX=',F7.2,' M'/)                            PMT12110
 1007 FORMAT(14X,'SOURCE',8X,'EMISSION RATES',61X,'WIND SPEED AT',4X,   PMT12120
     1 'MAXIMUM',/' POINT',6X,'COORDINATES',4X,'POL-1',6X,'POL-2',4X,   PMT12130
     2 'HEIGHT  DIAMETER  EXIT VEL  EXIT TEMP',6X,'DOMINANT',5X,        PMT12140
     3 'STACK HEIGHT',4X,'EFFECTIVE'/' SOURCE',3X,'X(KM)',4X,'Y(KM)',3X,PMT12150
     4 '(G/S)',6X,'(G/S)',5X,'(M)',6X,'(M)',7X,'(M/S)',4X,'(DEG K)',6X, PMT12160
     5 'INFLUENCE',8X,'(M/S)',6X,'SOURCE HEIGHT(M)'/)                   PMT12170
 1010 FORMAT(1X,I4,2X,F8.2,1X,F8.2,2X,F8.2,2X,F8.2,2X,F7.2,3X,F6.3,3X,  PMT12180
     1 F8.3,3X,F7.2,2X,2A4,1X,2A4,3X,F7.3,8X,F8.2)                      PMT12190
 1012 FORMAT(2X,I3,5(1X,F7.1),3(2X,F6.2),2(1X,2A4),2X,F6.2,             PMT12200
     1 5X,F8.2,8X,F5.3)                                                 PMT12210
      END                                                               PMT12220
C                                                                       PMT12230
```

```
C
C
      SUBROUTINE QZCAL
                    SUBROUTINE QZCAL , PART OF PEM-2 (VERSION 84130).
C
C
C
C   SUBROUTINE QZCAL CALCULATES QZC1 AND QZC2,  REPRESENTING THE
C      PROBABLITY DENSITIES OF VERTICAL DISTRIBUTIONS OF CONCENTRATIONS
C      OF POLLUTANT SPECIES 1 AND 2, RESPECTIVELY, AT A GIVEN
C      DISTANCE DOWNWIND OF A POINT SOURCE.
C
C
C
C *** PEM  ALGORITHMS AND PROGRAM DEVELOPMENT: ---DECEMBER 1982
C *** PEM-2 MODIFICATIONS: DECEMBER 1983
C
C      K. SHANKAR RAO, PHYSICAL SCIENTIST
C      ATMOSPHERIC TURBULENCE AND DIFFUSION LABORATORY (ATDL)
C      NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION (NOAA)
C      U.S. DEPARTMENT OF COMMERCE, P.O. BOX - E
C      OAK RIDGE, TENNESSEE 37831
C
C      ( THIS WORK WAS DONE UNDER AN INTERAGENCY AGREEMENT
C      BETWEEN THE ENVIRONMENTAL PROTECTION AGENCY AND THE
C      NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION )
C
C
C
C
      COMMON/PEMCOM/CONC(50,50,2),SDF(50,50,2),TT(20),
     1 XP(300),YP(300),EP(300,2),HP(300),DP(300),VP(300),TP(300),
     2 XA(50),YA(50),EA(50,2),SIZE(50),
     3 WD(24),WS(24),TA(24),HMIX(24),DTDZI(24),
     4 AZ(6),BZ(6),CZ(6),P(6),SCLAB(6),DTDZ(2),SECTAN(16),
     5 XSWC,YSWC,GRID,LX,LY,A(2),B(2),POLNAM(3,2),CALNAM(7,2),
     6 ITA,IRD,IWR,IDSK,D80,D47,D8047,DIST,DELTA,HPRIME,
     7 ESH(2),PEAK,IBUOY,IRISE,IDWN,EFF,XS,UINV,WVEC,
     8 NAS,NPS,INDEX,IGRID,IAV,ISCEN,IWDOPT,IWD,ISC,IPS,
     9 NTOPT,NWDOPT,NWSOPT,NWPOPT,NSCEN,NLIST,NARRAY,NTAPE,NCSOPT,
     * NMAX,NSTDWN,NPRISE,NINPEN,INTER,NPRINT,NGPR,NBID
C
      COMMON/PARM1/NPOL,VD1,W1,VD2,W2
      COMMON/PARM1A/ICT,TAUC,GAMMA
      COMMON/PARM2/ISPEC,UTAUC,Q2Q1,XCT,EXCT
      COMMON/PARM3/HC,VDC1,WC1,VDC2,WC2
      COMMON/PARM4/V11,V21,V12,V22,V13
      COMMON/PARM5/D11,D21,D12,D22,D31,D32,D33,D6
      COMMON/PARM6/R11,R21,R12,R22,R13,R23,R31,R41,R32,R42
      COMMON/PARM7/QZC1,QZC2,HGT
      COMMON/BLOCK1/PI,SQPI,SQRT2,A1B,A1C
      COMMON/BLOCK2/AI,BI,EPSABS,EPSREL,LW,NIW
      COMMON/EXPCHK/EXPMAX,EXPMIN,ETAMAX
      EXTERNAL FUN1
      REAL*8 FUN1
      REAL*8 WORK(800),AI,BI,EPSABS,EPSREL,RESULT,ABSERR
      DIMENSION IW(102)
C
C
C
      IF(DIST.GE.PEAK) GO TO 5
C. TEST FOR GRADUAL PLUME RISE AND BID OPTIONS.
C. IF DIST IS LESS THAN FINAL RISE, THEN USE GRAD. RISE IF BID SELECTED
C. AND USE THE GRADUAL RISE HEIGHT FOR EFFECTIVE PLUME HEIGHT,
C.  OTHERWISE USE FINAL PLUME HEIGHT (ESH(2)).
C.
C. OMIT CALL RISE, IF NGPR=1 (I.E. FINAL RISE) AND NBID=0 (I.E. NO BID)
      IF(NGPR.EQ.1.AND.NBID.EQ.0) GO TO 5
C
C  CALL SUBROUTINE RISE FOR EFFECTIVE SOURCE HEIGHT AT DOWNWIND
C    DISTANCE = DIST, LESS THAN DISTANCE TO MAXIMUM HEIGHT (PEAK).
C      ************
      CALL RISE
```

```
C     *************                                                     PMT12860
      HGT= ESH(1)                                                       PMT12870
      GO TO 6                                                           PMT12880
C                                                                       PMT12890
C  USE MAXIMUM EFFECTIVE SOURCE HEIGHT, SINCE DOWNWIND DISTANCE         PMT12900
C     EXCEEDS THE DISTANCE TO MAXIMUM HEIGHT.                           PMT12910
    5 HGT= ESH(2)                                                       PMT12920
C                                                                       PMT12930
C                                                                       PMT12940
    6 HL=HMIX(ISCEN)                                                    PMT12950
      X=DIST                                                            PMT12960
      XM=X*1000.                                                        PMT12970
      SIGZ= AZ(ISC)*XM*(1.+CZ(ISC)*XM)/(SQRT(1.+BZ(ISC)*XM))            PMT12980
C. CHECK FOR BID OPTION. NBID=1 , BID ON                                PMT12981
      IF(NBID.EQ.0) GO TO 3                                             PMT12982
C.  CONSIDER BOUYANCY INDUCED DISPERSION (BID)                          PMT12983
      DH=HGT-HPRIME                                                     PMT12984
      SIGB=DH/3.5                                                       PMT12985
      SIGB=SIGB*SIGB                                                    PMT12986
      SIGZ=SQRT(SIGZ*SIGZ + SIGB)                                       PMT12987
    3 IF(SIGZ.GT.5000.) SIGZ=5000.                                      PMT12990
      SZ=SIGZ                                                           PMT13000
      C2=SQRT2*SZ                                                       PMT13010
      HC=HGT/C2                                                         PMT13020
      IF(NGPR.EQ.1) HC=ESH(2)/C2                                        PMT13021
      XC=XM/C2                                                          PMT13030
C                                                                       PMT13040
C     ISPEC = 1 OR 2 OR 3                                               PMT13050
      D31=2.*V11*XC                                                     PMT13060
      D11=WC1*XC                                                        PMT13070
      D21=D11*D11                                                       PMT13080
      R31=1.+2.*D21                                                     PMT13090
      R41=2.*D11/SQPI                                                   PMT13100
      IF(ISPEC.EQ.1) GO TO 9                                            PMT13110
C                                                                       PMT13120
C     ISPEC = 2 OR 3                                                    PMT13130
      D32=2.*V12*XC                                                     PMT13140
      D12=WC2*XC                                                        PMT13150
      D22=D12*D12                                                       PMT13160
      R32=1.+2.*D22                                                     PMT13170
      R42=2.*D12/SQPI                                                   PMT13180
      IF(ISPEC.EQ.2) GO TO 10                                           PMT13190
C                                                                       PMT13200
C     ISPEC = 3                                                         PMT13210
      D33=2.*V13*XC                                                     PMT13220
      D6=4.*SQPI*(V21-V22)*XC                                           PMT13230
C                                                                       PMT13240
    9 TCC=UTAUC/C2                                                      PMT13250
   10 IF(ICT.EQ.0) XCT=0.                                               PMT13260
      IF(ICT.EQ.1) XCT=XC/TCC                                           PMT13270
      EXCT=EXP(-XCT)                                                    PMT13280
C                                                                       PMT13290
      TERM1=0.                                                          PMT13300
      TERM2=0.                                                          PMT13310
      TERM3=0.                                                          PMT13320
C                                                                       PMT13330
      DUM1=D47+0.001                                                    PMT13340
      DUM2=D80-0.001                                                    PMT13350
      IF(X.LT.DUM1) GO TO 100                                           PMT13360
      IF(X.GT.DUM2) GO TO 200                                           PMT13370
C                                                                       PMT13380
   11 QZC1=0.0                                                          PMT13390
      QZC2=0.0                                                          PMT13400
      RETURN                                                            PMT13410
C                                                                       PMT13420
C                                                                       PMT13430
C **** NEAR-SOURCE REGION (X .LE. D47).                                 PMT13440
C                                                                       PMT13450
  100 M=1                                                               PMT13460
      A1=A1B/SZ                                                         PMT13470
      C3=HC*HC                                                          PMT13480
      IF(C3.GE.EXPMIN) GO TO 11                                         PMT13490
      A2=1./EXP(C3)                                                     PMT13500
C                                                                       PMT13510
C     ISPEC = 1 OR 2 OR 3                                               PMT13520
C     SPECIES-1 (PRIMARY) POLLUTANT: GAS OR PARTICLES.                  PMT13530
      ETA1=HC+D31                                                       PMT13540
      ETA1SQ=ETA1*ETA1                                                  PMT13550
      IF(ETA1SQ.GT.EXPMAX) CALL ARGCHK(ETA1,ETA1SQ)                     PMT13560
      B11=EXP(ETA1SQ)*ERFC(ETA1)                                        PMT13570
      ALPHA1=A1C*D31*B11                                                PMT13580
      SUM=2.-ALPHA1                                                     PMT13590
      IF(SUM) 115,115,116                                               PMT13600
  115 G21P=0.0                                                          PMT13610
      GO TO 120                                                         PMT13620
  116 IF(WC1.EQ.0.) GO TO 117                                           PMT13630
      BETA1=-2.*D11*HC+D21                                              PMT13640
      CALL EXPO(-BETA1,EBT1)                                            PMT13650
      GO TO 118                                                         PMT13660
  117 EBT1=1.0                                                          PMT13670
  118 G21P=EXCT*EBT1*A2*SUM                                             PMT13680
  120 QZC1=A1*G21P                                                      PMT13690
      IF(ISPEC.EQ.1) RETURN                                             PMT13700
C                                                                       PMT13710
C                                                                       PMT13720
C     ISPEC = 2 OR 3                                                    PMT13730
C     SPECIES-2 (SECONDARY) POLLUTANT: GAS OR PARTICLES.                PMT13740
      ETA2=HC+D32                                                       PMT13750
      ETA2SQ=ETA2*ETA2                                                  PMT13760
      IF(ETA2SQ.GT.EXPMAX) CALL ARGCHK(ETA2,ETA2SQ)                     PMT13770
      B12=EXP(ETA2SQ)*ERFC(ETA2)                                        PMT13780
      ALPHA2=A1C*D32*B12                                                PMT13790
      SUM1=2.-ALPHA2                                                    PMT13800
      IF(ISPEC.EQ.3) GO TO 145                                          PMT13810
C                                                                       PMT13820
C     ISPEC = 2                                                         PMT13830
      IF(SUM1) 135,135,140                                              PMT13840
  135 G22P=0.0                                                          PMT13850
      QZC2=0.0                                                          PMT13860
      RETURN                                                            PMT13870
  140 IF(WC2.EQ.0.) GO TO 141                                           PMT13880
      BETA2=-2.*D12*HC+D22                                              PMT13890
      CALL EXPO(-BETA2,EBT2)                                            PMT13900
      GO TO 142                                                         PMT13910
  141 EBT2=1.0                                                          PMT13920
  142 G22P=EBT2*A2*SUM1                                                 PMT13930
      QZC2=A1*G22P                                                      PMT13940
      RETURN                                                            PMT13950
C                                                                       PMT13960
C     ISPEC = 3                                                         PMT13970
  145 TERM1=(Q2Q1+GAMMA)*A2*SUM1                                        PMT13980
C                                                                       PMT13990
      ETA3=HC+D33                                                       PMT14000
      ETA3SQ=ETA3*ETA3                                                  PMT14010
      IF(ETA3SQ.GT.EXPMAX) CALL ARGCHK(ETA3,ETA3SQ)                     PMT14020
      B13=EXP(ETA3SQ)*ERFC(ETA3)                                        PMT14030
      ALPHA3=A1C*D33*B13                                                PMT14040
      TERM2=-GAMMA*EXCT*A2*(2.-ALPHA3)                                  PMT14050
C                                                                       PMT14060
      IF(V21.EQ.V22) GO TO 150                                          PMT14070
C     COMPUTE INTEGRAL FUNC=F1(XC,0.;HC); FUN1 IS THE INTEGRAND FUNCTIONPMT14080
      CALL D01AJF(FUN1,AI,BI,EPSABS,EPSREL,RESULT,                      PMT14090
     1   ABSERR,WORK,LW,IW,NIW,IFAIL)                                   PMT14100
      RES=RESULT                                                        PMT14110
      FUNC=RES/PI                                                       PMT14120
      TERM3=-GAMMA*D6*FUNC                                              PMT14130
C                                                                       PMT14140
  150 SUMT=TERM1+TERM2+TERM3                                            PMT14150
      IF(SUMT) 155,155,160                                              PMT14160
  155 G22P=0.0                                                          PMT14170
```

```
      QZC2=0.0
      RETURN
  160 IF(WC2.EQ.0.) GO TO 161
      BETA2=-2.*D12*HC+D22
      CALL EXPO(-BETA2,EBT2)
      GO TO 162
  161 EBT2=1.0
  162 G22P=EBT2*SUMT
      QZC2=A1*G22P
      RETURN
C
C
C **** WELL-MIXED REGION (X .GE. D80).
C
C     IN THIS REGION, THE CONCENTRATION BELOW THE MIXING HEIGHT IS
C     UNIFORM REGARDLESS OF THE SOURCE OR RECEPTOR HEIGHTS BECAUSE
C     OF THOROUGH MIXING OF POLLUTANT BETWEEN THE GROUND AND THE
C     MIXING HEIGHT.
C
  200 M=2
      A1A=1000./HL
      CALL PSG4P(G41P,G42P)
      QZC1=A1A*G41P
      IF(ISPEC.EQ.1) RETURN
      QZC2=A1A*G42P
      RETURN
      END
C
C
C

      SUBROUTINE PSG4P(G41P,G42P)
C                     SUBROUTINE PSG4P , PART OF PEM-2 (VERSION 84130).
C
C
C     THIS SUBROUTINE CALCULATES AND RETURNS VALUES OF G41P AND G42P.
C     THESE ARE NONDIMENSIONAL VERTICALLY-INTEGRATED PROBABILITY
C     DENSITY FUNCTIONS USED IN THE WELL-MIXED REGION CONCENTRATION
C     ALGORITHMS FOR SPECIES-1 AND SPECIES-2, RESPECTIVELY, DOWNWIND
C     OF A POINT SOURCE.  THESE FUNCTIONS ARE INDEPENDENT OF BOTH
C     SOURCE HEIGHT AND RECEPTOR HEIGHT.
C
C
C
C *** PEM ALGORITHMS AND PROGRAM DEVELOPMENT: --- DECEMBER 1982
C
C     K. SHANKAR RAO, PHYSICAL SCIENTIST
C     ATMOSPHERIC TURBULENCE AND DIFFUSION LABORATORY (ATDL)
C     NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION (NOAA)
C     U.S. DEPARTMENT OF COMMERCE, P.O. BOX - E
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C
C     ( THIS WORK WAS DONE UNDER AN INTERAGENCY AGREEMENT
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C     NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION )
C
C
C
      EXTERNAL FUN2
      REAL*8 FUN2
      REAL*8 WORK(800),AI,BI,EPSABS,EPSREL,RESULT,ABSERR
      DIMENSION IW(102)
      COMMON/PARM1A/ICT,TAUC,GAMMA
      COMMON/PARM2/ISPEC,UTAUC,Q2Q1,XCT,EXCT
      COMMON/PARM4/V11,V21,V12,V22,V13
      COMMON/PARM5/D11,D21,D12,D22,D31,D32,D33,D6
      COMMON/PARM6/R11,R21,R12,R22,R13,R23,R31,R41,R32,R42
      COMMON/BLOCK1/PI,SQPI,SQRT2,A1B,A1C
      COMMON/BLOCK2/AI,BI,EPSABS,EPSREL,LW,NIW
      COMMON/EXPCHK/EXPMAX,EXPMIN,ETAMAX
C
```

```
C                                                                       PMT14870
C     ISPEC = 1 OR 2 OR 3                                               PMT14880
C***** SPECIES-1 (PRIMARY) POLLUTANT: GAS OR PARTICLES.                 PMT14890
C                                                                       PMT14900
      IF(D21.GT.EXPMAX) CALL ARGCHK(D11,D21)                            PMT14910
      B11=EXP(D21)*ERFC(D11)                                            PMT14920
      IF(V21.EQ.0.) GO TO 201                                           PMT14930
      D31SQ=D31*D31                                                     PMT14940
      IF(D31SQ.GT.EXPMAX) CALL ARGCHK(D31,D31SQ)                        PMT14950
      SUM=R11*(EXP(D31SQ)*ERFC(D31))-R21*B11                            PMT14960
      GO TO 202                                                         PMT14970
  201 SUM=R31*B11-R41                                                   PMT14980
  202 IF(SUM.LT.0.) SUM=0.0                                             PMT14990
      G41P=EXCT*EXP(-D21)*SUM                                           PMT15000
      IF(ISPEC.EQ.1) RETURN                                             PMT15010
C                                                                       PMT15020
C     ISPEC = 2 OR 3                                                    PMT15030
C***** SPECIES-2 (SECONDARY) POLLUTANT: GAS OR PARTICLES.               PMT15040
C                                                                       PMT15050
      IF(D22.GT.EXPMAX) CALL ARGCHK(D12,D22)                            PMT15060
      B12=EXP(D22)*ERFC(D12)                                            PMT15070
      IF(V22.EQ.0.) GO TO 203                                           PMT15080
      D32SQ=D32*D32                                                     PMT15090
      IF(D32SQ.GT.EXPMAX) CALL ARGCHK(D32,D32SQ)                        PMT15100
      SUM1=R12*(EXP(D32SQ)*ERFC(D32))-R22*B12                           PMT15110
      GO TO 204                                                         PMT15120
  203 SUM1=R32*B12-R42                                                  PMT15130
  204 IF(ISPEC.EQ.3) GO TO 205                                          PMT15140
C                                                                       PMT15150
C     ISPEC = 2                                                         PMT15160
      IF(SUM1.LT.0.) SUM1=0.0                                           PMT15170
      G42P=EXP(-D22)*SUM1                                               PMT15180
      RETURN                                                            PMT15190
C                                                                       PMT15200
C     ISPEC = 3                                                         PMT15210
  205 TERM1=(Q2Q1+GAMMA)*SUM1                                           PMT15220
C                                                                       PMT15230
      IF(V21.EQ.0.) GO TO 206                                           PMT15240
      D33SQ=D33*D33                                                     PMT15250
      IF(D33SQ.GT.EXPMAX) CALL ARGCHK(D33,D33SQ)                        PMT15260
      SUM2=R13*(EXP(D33SQ)*ERFC(D33))-R23*B12                           PMT15270
      GO TO 207                                                         PMT15280
  206 SUM2=R32*B12-R42                                                  PMT15290
  207 TERM2=-GAMMA*EXCT*SUM2                                            PMT15300
C                                                                       PMT15310
      IF(V21.EQ.V22) GO TO 208                                          PMT15320
C     COMPUTE INTEGRAL FUNC=F2(XC); FUN2 IS THE INTEGRAND FUNCTION.     PMT15330
      CALL D01AJF(FUN2,AI,BI,EPSABS,EPSREL,RESULT,                      PMT15340
     1  ABSERR,WORK,LW,IW,NIW,IFAIL)                                    PMT15350
      RES=RESULT                                                        PMT15360
      FUNC=RES/(2.*PI)                                                  PMT15370
      TERM3=-GAMMA*D6*FUNC                                              PMT15380
      GO TO 209                                                         PMT15390
  208 TERM3=0.0                                                         PMT15400
C                                                                       PMT15410
  209 SUMT=TERM1+TERM2+TERM3                                            PMT15420
      IF(SUMT.LT.0.) SUMT=0.0                                           PMT15430
      G42P=EXP(-D22)*SUMT                                               PMT15440
      RETURN                                                            PMT15450
      END                                                               PMT15460
C
C                                                                       PMT15470
C                                                                       PMT15480
      DOUBLE PRECISION FUNCTION FUN1(T)                                 PMT15490
C                  REAL*8 FUNCTION FUN1 , PART OF PEM-2 (VERSION 84130).PMT15500
C                                                                       PMT15510
C                                                                       PMT15520
C     INTEGRAND FUNCTION USED IN THE NUMERICAL INTEGRATION IN SUBROUTINEPMT15530
C     QZCAL (FOR POINT SOURCES) IS DEFINED HERE.                        PMT15540
C                                                                       PMT15550
```

```
C
C     PEM-2 ALGORITHMS AND PROGRAM DEVELOPMENT: DECEMBER 1982
C     K. SHANKAR RAO
C     NOAA-ATDL, P.O. BOX-E
C     OAK RIDGE, TENN 37830
C
C
C       FOR UNIVAC-1100
        REAL*8 T
C
      COMMON/PARM2/ISPEC,UTAUC,Q2Q1,XCT,EXCT
      COMMON/PARM3/HC,VDC1,WC1,VDC2,WC2
      COMMON/PARM5/D11,D21,D12,D22,D31,D32,D33,D6
      COMMON/BLOCK1/PI,SQPI,SQRT2,A1B,A1C
      COMMON/EXPCHK/EXPMAX,EXPMIN,ETAMAX
C
C
      SQT=SQRT(T)
      SQ1T=SQRT(1.-T)
      HC1=HC/SQT
C
      ARG1=(HC1*HC1)+(T*XCT)
      CALL EXPO(-ARG1,EXP1)
      IF(EXP1.EQ.0.) GO TO 10
      TERM1= EXP1/(SQT*SQ1T)
C
      ETA4=HC1+D33*SQT
      ETA4SQ=ETA4*ETA4
      IF(ETA4SQ.GT.EXPMAX) CALL ARGCHK(ETA4,ETA4SQ)
      TERM2A= EXP(ETA4SQ)*ERFC(ETA4)
      HC1SQ=HC1*HC1
      IF(HC1SQ.GT.EXPMAX) CALL ARGCHK(HC1,HC1SQ)
      TERM2=1.-SQPI*(ETA4-HC1)*TERM2A
      IF(TERM2.LE.0.) GO TO 10
C
      ETA5=D32*SQ1T
      ETA5SQ=ETA5*ETA5
      IF(ETA5SQ.GT.EXPMAX) CALL ARGCHK(ETA5,ETA5SQ)
      TERM3=1.-SQPI*ETA5*(EXP(ETA5SQ)*ERFC(ETA5))
      IF(TERM3.LE.0.) GO TO 10
C
      FUN1=TERM1*TERM2*TERM3
      GO TO 11
   10 FUN1=0.0
   11 RETURN
      END
C
C
C
      DOUBLE PRECISION FUNCTION FUN1A(T)
C                REAL*8 FUNCTION FUN1A , PART OF PEM-2 (VERSION 84130).
C
C
C     INTEGRAND FUNCTION USED IN THE NUMERICAL INTEGRATION FOR AREA
C     SOURCES (POLLUTANT SPECIES-2) IN FUNCTION FUN4 IS DEFINED HERE.
C
C
C     PEM-2 ALGORITHMS AND PROGRAM DEVELOPMENT: DECEMBER 1983
C     K. SHANKAR RAO, NOAA-ATDL, OAK RIDGE, TENN.
C
C     FOR UNIVAC-1100
      REAL*8 T
C
      COMMON/BLOCK1/PI,SQPI,SQRT2,A1B,A1C
      COMMON/CLOCK1/ET2,ET3,HCA,XCAT
      COMMON/EXPCHK/EXPMAX,EXPMIN,ETAMAX
C
C
      SQT=SQRT(T)
      SQ1T=SQRT(1.-T)
      HC1=HCA/SQT                                                       PMT16250
      D33SQT=ET3*SQT                                                    PMT16260
C                                                                       PMT16270
      ARG1=HC1*HC1+XCAT*T                                               PMT16280
      CALL EXPO(-ARG1,EXP1)                                             PMT16290
      TERM1=EXP1/(SQT*SQ1T)                                             PMT16300
      IF(TERM1.LE.0.) GO TO 10                                          PMT16310
C                                                                       PMT16320
      ETA4=HC1+D33SQT                                                   PMT16330
      ETA4SQ=ETA4*ETA4                                                  PMT16340
      IF(ETA4SQ.GT.EXPMAX) CALL ARGCHK(ETA4,ETA4SQ)                     PMT16350
      TERM2=1.-SQPI*D33SQT*EXP(ETA4SQ)*ERFC(ETA4)                       PMT16360
      IF(TERM2.LE.0.) GO TO 10                                          PMT16370
C                                                                       PMT16380
      ETA5=ET2*SQ1T                                                     PMT16390
      ETA5SQ=ETA5*ETA5                                                  PMT16400
      IF(ETA5SQ.GT.EXPMAX) CALL ARGCHK(ETA5,ETA5SQ)                     PMT16410
      TERM3=1.-SQPI*ETA5*EXP(ETA5SQ)*ERFC(ETA5)                         PMT16420
      IF(TERM3.LE.0.) GO TO 10                                          PMT16430
C                                                                       PMT16440
      FUN1A=TERM1*TERM2*TERM3                                           PMT16450
      GO TO 20                                                          PMT16460
   10 FUN1A=0.                                                          PMT16470
   20 RETURN                                                            PMT16480
      END                                                               PMT16490
C
C                                                                       PMT16500
C                                                                       PMT16510
      DOUBLE PRECISION FUNCTION FUN2(T)                                 PMT16520
C                 REAL*8 FUNCTION FUN2 , PART OF PEM-2 (VERSION 84130). PMT16530
C                                                                       PMT16540
C                                                                       PMT16550
C     INTEGRAND FUNCTION USED IN THE NUMERICAL INTEGRATION FOR POINT    PMT16560
C     SOURCES (POLLUTANT SPECIES-2) IN SUBROUTINE PSG4P IS DEFINED HERE.PMT16570
C                                                                       PMT16580
C                                                                       PMT16590
C     PEM ALGORITHMS AND PROGRAM DEVELOPMENT: DECEMBER 1982              PMT16600
C     K. SHANKAR RAO                                                    PMT16610
C     NOAA-ATDL, P.O. BOX-E                                             PMT16620
C     OAK RIDGE, TENN 37830                                             PMT16630
C                                                                       PMT16640
C                                                                       PMT16650
C     FOR UNIVAC-1100                                                   PMT16660
      REAL*8 T                                                          PMT16670
C                                                                       PMT16680
      COMMON/PARM2/ISPEC,UTAUC,Q2Q1,XCT,EXCT                            PMT16690
      COMMON/PARM4/V11,V21,V12,V22,V13                                  PMT16700
      COMMON/PARM5/D11,D21,D12,D22,D31,D32,D33,D6                       PMT16710
      COMMON/PARM6/R11,R21,R12,R22,R13,R23,R31,R41,R32,R42              PMT16720
      COMMON/BLOCK1/PI,SQPI,SQRT2,A1B,A1C                               PMT16730
      COMMON/EXPCHK/EXPMAX,EXPMIN,ETAMAX                                PMT16740
C                                                                       PMT16750
C                                                                       PMT16760
      SQT=SQRT(T)                                                       PMT16770
      SQ1T=SQRT(1.-T)                                                   PMT16780
      ETA4=D33*SQT                                                      PMT16790
      ETA5=D32*SQ1T                                                     PMT16800
      ETA6=D12*SQ1T                                                     PMT16810
      ETA6SQ=ETA6*ETA6                                                  PMT16820
      IF(ETA6SQ.GT.EXPMAX) CALL ARGCHK(ETA6,ETA6SQ)                     PMT16830
C                                                                       PMT16840
      ARG1=T*XCT                                                        PMT16850
      EXP1=EXP(-ARG1)                                                   PMT16860
      TERM1=EXP1/SQT                                                    PMT16870
C                                                                       PMT16880
      ETA4SQ=ETA4*ETA4                                                  PMT16890
      IF(ETA4SQ.GT.EXPMAX) CALL ARGCHK(ETA4,ETA4SQ)                     PMT16900
      TERM2=1.-SQPI*ETA4*(EXP(ETA4SQ)*ERFC(ETA4))                       PMT16910
      IF(TERM2.LE.0.) GO TO 15                                          PMT16920
C                                                                       PMT16930
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```
   11 IF(V22.EQ.0.) GO TO 12
      ETA5SQ=ETA5*ETA5
      IF(ETA5SQ.GT.EXPMAX) CALL ARGCHK(ETA5,ETA5SQ)
      T3A=EXP(ETA5SQ)*ERFC(ETA5)
      T3B=EXP(ETA6SQ)*ERFC(ETA6)
      TERM3=R12*T3A-R22*T3B
      IF(TERM3.LE.0.) GO TO 15
      GO TO 13
C
   12 T3A=(1.+2.*ETA6SQ)*(EXP(ETA6SQ)*ERFC(ETA6))
      T3B=2.*ETA6/SQPI
      TERM3=T3A-T3B
      IF(TERM3.LE.0.) GO TO 15
C
   13 FUN2=TERM1*TERM2*TERM3
      GO TO 16
   15 FUN2=0.
   16 RETURN
      END
C
C
C
      DOUBLE PRECISION FUNCTION FUN3(XA)
C                REAL*8 FUNCTION FUN3 , PART OF PEM-2 (VERSION 84130).
C
C
C     INTEGRAND FUNCTION USED IN THE NUMERICAL INTEGRATION FOR AREA
C     SOURCES (POLLUTANT SPECIES-1) IN MAIN PROGRAM IS DEFINED HERE.
C
C
C     PEM-2 ALGORITHMS AND PROGRAM DEVELOPMENT: DECEMBER 1983
C     K. SHANKAR RAO
C     NOAA-ATDL, P.O. BOX - E
C     OAK RIDGE, TENN 37830
C
C
C     FOR UNIVAC-1100
      REAL*8 XA
C
      COMMON/PARM1A/ICT,TAUC,GAMMA
      COMMON/PARM2/ISPEC,UTAUC,Q2Q1,XCT,EXCT
      COMMON/PARM2A/HAS,KSC,AA,BA,CA
      COMMON/PARM3/HC,VDC1,WC1,VDC2,WC2
      COMMON/PARM4/V11,V21,V12,V22,V13
      COMMON/BLOCK1/PI,SQPI,SQRT2,A1B,A1C
      COMMON/EXPCHK/EXPMAX,EXPMIN,ETAMAX
C
C
      SIGZ=AA*XA*(1.+CA*XA)/SQRT(1.+BA*XA)
      C2=SQRT2*SIGZ
      XCA=XA/C2
      HCA=HAS/C2
      D31=2.*V11*XCA
C
      ETA1=HCA+D31
      ETA1SQ=ETA1*ETA1
      IF(ETA1SQ.GT.EXPMAX) CALL ARGCHK(ETA1,ETA1SQ)
      TERM1=1.-SQPI*D31*EXP(ETA1SQ)*ERFC(ETA1)
      IF(TERM1.LE.0.) GO TO 25
C
      BETA1=HCA-WC1*XCA
      ARG1=BETA1*BETA1
      IF(ISPEC.EQ.2) GO TO 20
      IF(ISPEC.EQ.1.AND.ICT.EQ.0) GO TO 20
      IF(UTAUC.GT.0.) ARG1=ARG1+XA/UTAUC
   20 CALL EXPO(-ARG1,EXP1)
C
      FUN3=EXP1*TERM1/SIGZ
      GO TO 30
   25 FUN3=0.
   30 RETURN
      END
C
C
C
      DOUBLE PRECISION FUNCTION FUN4(XA)
C                 REAL*8 FUNCTION FUN4 , PART OF PEM-2 (VERSION 84130).
C
C     INTEGRAND FUNCTION USED IN THE NUMERICAL INTEGRATION FOR AREA
C     SOURCES (POLLUTANT SPECIES-2) IN THE MAIN PROGRAM IS DEFINED HERE.
C     THIS FUNCTION CONSISTS ONLY OF THE CHEMICAL TRANSFORMATION
C     CONTRIBUTION TO THE SPECIES-2 CONCENTRATION BUDGET.
C
C
C     PEM-2 ALGORITHMS AND PROGRAM DEVELOPMENT: DECEMBER 1983
C     K. SHANKAR RAO
C     NOAA-ATDL, P.O.BOX-E
C     OAK RIDGE, TENN 37830
C
C
      REAL*8 WORK(800),AI,BI,EPSABS,EPSREL,RESULT,ABSERR
      EXTERNAL FUN1A
      REAL*8 FUN1A
C     FOR UNIVAC-1100
      REAL*8 XA
C
      DIMENSION IW(102)
      COMMON/PARM2/ISPEC,UTAUC,Q2Q1,XCT,EXCT
      COMMON/PARM2A/HAS,KSC,AA,BA,CA
      COMMON/PARM3/HC,VDC1,WC1,VDC2,WC2
      COMMON/PARM4/V11,V21,V12,V22,V13
      COMMON/BLOCK1/PI,SQPI,SQRT2,A1B,A1C
      COMMON/BLOCK2/AI,BI,EPSABS,EPSREL,LW,NIW
      COMMON/CLOCK1/ET2,ET3,HCA,XCAT
      COMMON/EXPCHK/EXPMAX,EXPMIN,ETAMAX
C
      SIGZ=AA*XA*(1.+CA*XA)/SQRT(1.+BA*XA)
      C2=SQRT2*SIGZ
      XCA=XA/C2
      HCA=HAS/C2
      D32=2.*V12*XCA
      D33=2.*V13*XCA
C
      ETA2=HCA+D32
      ETA2SQ=ETA2*ETA2
      IF(ETA2SQ.GT.EXPMAX) CALL ARGCHK(ETA2,ETA2SQ)
      TERM1=1.-SQPI*D32*EXP(ETA2SQ)*ERFC(ETA2)
      IF(TERM1.LE.0.) GO TO 30
C
      ETA3=HCA+D33
      ETA3SQ=ETA3*ETA3
      IF(ETA3SQ.GT.EXPMAX) CALL ARGCHK(ETA3,ETA3SQ)
      TERM2A=1.-SQPI*D33*EXP(ETA3SQ)*ERFC(ETA3)
      IF(TERM2A.LE.0.) TERM2A=0.
      XCAT=XA/UTAUC
      TERM2=EXP(-XCAT)*TERM2A
C
      IF(V21.EQ.V22) GO TO 20
      TERM3A=SQPI*2.*(V21-V22)*XCA
      ET2=D32
      ET3=D33
C     COMPUTE INTEGRAL F1A(AI,BI); FUN1A IS THE EXTERNALLY DEFINED
C     INTEGRAND FUNCTION.
      CALL D01AJF(FUN1A,AI,BI,EPSABS,EPSREL,RESULT,
     1   ABSERR,WORK,LW,IW,NIW,IFAIL)
      TERM3=TERM3A*RESULT/PI
      GO TO 25
   20 TERM3=0.
C
```

```
   25 BETA2=HCA-WC2*XCA
      B2SQ=BETA2*BETA2
      CALL EXPO(-B2SQ,EB2SQ)
      B3SQ=B2SQ-HCA*HCA
      CALL EXPO(-B3SQ,EB3SQ)
      FUN4=(EB2SQ*(TERM1-TERM2)-EB3SQ*TERM3)/SIGZ
      GO TO 35
   30 FUN4=0.
   35 RETURN
      END
C
C
C
      DOUBLE PRECISION FUNCTION FUN5(XA)
C                 REAL*8 FUNCTION FUN5 , PART OF PEM-2 (VERSION 84130).
C
C
C
C     INTEGRAND FUNCTION USED IN THE NUMERICAL INTEGRATION FOR AREA
C     SOURCES (POLLUTANT SPECIES-2) IN THE MAIN PROGRAM IS DEFINED HERE.
C     THIS FUNCTION CONSISTS ONLY OF THE CONTRIBUTION OF THE DIRECT
C     EMISSION OF SPECIES-2 TO THE CONCENTRATION BUDGET.
C
C
C     PEM-2 ALGORITHMS AND PROGRAM DEVELOPMENT: FEBRUARY 1984
C     K. SHANKAR RAO
C     NOAA-ATDL, P.O. BOX-E
C     OAK RIDGE, TENN 37830
C
C
C     FOR UNIVAC-1100
        REAL*8 XA
C
      COMMON/PARM2A/HAS,KSC,AA,BA,CA
      COMMON/PARM3/HC,VDC1,WC1,VDC2,WC2
      COMMON/PARM4/V11,V21,V12,V22,V13
      COMMON/BLOCK1/PI,SQPI,SQRT2,A1B,A1C
      COMMON/EXPCHK/EXPMAX,EXPMIN,ETAMAX
C
      SIGZ=AA*XA*(1.+CA*XA)/SQRT(1.+BA*XA)
      C2=SQRT2*SIGZ
      XCA=XA/C2
      HCA=HAS/C2
      D32=2.*V12*XCA
C
      ETA2=HCA+D32
      ETA2SQ=ETA2*ETA2
      IF(ETA2SQ.GT.EXPMAX) CALL ARGCHK(ETA2,ETA2SQ)
      TERM1=1.-SQPI*D32*EXP(ETA2SQ)*ERFC(ETA2)
      IF(TERM1.LE.0.) GO TO 10
C
      BETA2=HCA-WC2*XCA
      B2SQ=BETA2*BETA2
      CALL EXPO(-B2SQ,EB2SQ)
      FUN5=EB2SQ*TERM1/SIGZ
      GO TO 20
   10 FUN5=0.
   20 RETURN
      END
C
      SUBROUTINE EXPO(BX,EX)
C
C
C                      SUBROUTINE EXPO , PART OF PEM-2 (VERSION 84130).
C
C
C     GIVEN THE ARGUMENT BX, SUBROUTINE EXPO CALCULATES AND
C     RETURNS EX=EXP(BX).  EXPO LIMITS THE ARGUMENT TO AVOID
C     OVERFLOW/UNDERFLOW ERRORS.
C
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C                                                                       PMT19000
C     PEM ALGORITHMS AND PROGRAM DEVELOPMENT: DECEMBER 1982             PMT19010
C     K. SHANKAR RAO                                                    PMT19020
C     NOAA-ATDL, P.O. BOX-E                                             PMT19030
C     OAK RIDGE, TENN 37831                                             PMT19040
C                                                                       PMT19050
C                                                                       PMT19060
      COMMON/EXPCHK/EXPMAX,EXPMIN,ETAMAX                                PMT19070
C                                                                       PMT19080
C                                                                       PMT19090
      BXABS=ABS(BX)                                                     PMT19100
      IF(BX) 5,10,15                                                    PMT19110
    5 IF(BXABS-EXPMIN) 6,7,7                                            PMT19120
    6 EX=EXP(BX)                                                        PMT19130
      GO TO 20                                                          PMT19140
    7 EX=0.                                                             PMT19150
      GO TO 20                                                          PMT19160
   10 EX=1.                                                             PMT19170
      GO TO 20                                                          PMT19180
   15 IF(BXABS.GT.EXPMAX) BXABS=EXPMAX                                  PMT19190
      EX=EXP(BXABS)                                                     PMT19200
   20 RETURN                                                            PMT19210
      END                                                               PMT19220
C
C                                                                       PMT19230
C                                                                       PMT19240
      SUBROUTINE ARGCHK(E,ESQ)                                          PMT19250
C                     SUBROUTINE ARGCHK , PART OF PEM-2 (VERSION 84130). PMT19260
C                                                                       PMT19270
C                                                                       PMT19280
C     SUBROUTINE ARGCHK LIMITS THE ARGUMENTS OF EXP(ESQ)*ERFC(E)        PMT19290
C     TO AVOID OVERFLOW/UNDERFLOW ERRORS.                               PMT19300
C                                                                       PMT19310
C                                                                       PMT19320
C     PEM ALGORITHMS AND PROGRAM DEVELOPMENT:  DECEMBER 1982            PMT19330
C     K. SHANKAR RAO                                                    PMT19340
C     NOAA-ATDL, P.O. BOX-E                                             PMT19350
C     OAK RIDGE, TENN 37831                                             PMT19360
C                                                                       PMT19370
C                                                                       PMT19380
      COMMON/EXPCHK/EXPMAX,EXPMIN,ETAMAX                                PMT19390
C                                                                       PMT19400
C                                                                       PMT19410
      ESQ=EXPMAX                                                        PMT19420
      IF(E.LT.0.) NSIGN=-1                                              PMT19430
      IF(E.GE.0.) NSIGN=1                                               PMT19440
      E=NSIGN*ETAMAX                                                    PMT19450
      RETURN                                                            PMT19460
      END                                                               PMT19470
C
C                                                                       PMT19480
C                                                                       PMT19490
      SUBROUTINE INMOD                                                  PMT19500
C                     SUBROUTINE INMOD  , PART OF PEM-2 (VERSION 84130). PMT19510
C                                                                       PMT19520
C                                                                       PMT19530
C  SUBROUTINE INMOD READS IN ALL INPUTS TO THE MODEL, SCREENS THEM,     PMT19540
C    PRINTS WARNING MESSAGES, AND INSERTS DEFAULT VALUES AS NEEDED.     PMT19550
C    THE SUBROUTINE PRINTS OUT LISTS OF THE CONTROL PARAMETERS,         PMT19560
C    SCENARIO PARAMETERS, AND SOURCE DATA FOR REFERENCE.                PMT19570
C    INMOD ALSO PROCESSES THE INPUT FOR EACH SCENARIO BEFORE            PMT19580
C    TRANSMITTING IT TO THE MAIN PROGRAM.                               PMT19590
C                                                                       PMT19600
C                                                                       PMT19610
C *** PEM MODIFICATIONS AND FORMATS BY M.M. STEVENS,                    PMT19620
C     NOAA-ATDL, P.O. BOX-E, OAK RIDGE, TENN 37831                      PMT19630
C     DECEMBER 1982                                                     PMT19640
C *** PEM-2 MODIFICATIONS AND FORMATS BY K. SHANKAR RAO,                PMT19650
C     APRIL 1984                                                        PMT19660
C                                                                       PMT19670
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C                                                                       PMT19680
      COMMON/PEMCOM/CONC(50,50,2),SDF(50,50,2),TT(20),                  PMT19690
     1 XP(300),YP(300),EP(300,2),HP(300),DP(300),VP(300),TP(300),       PMT19700
     2 XA(50),YA(50),EA(50,2),SIZE(50),                                 PMT19710
     3 WD(24),WS(24),TA(24),HMIX(24),DTDZI(24),                         PMT19720
     4 AZ(6),BZ(6),CZ(6),P(6),SCLAB(6),DTDZ(2),SECTAN(16),              PMT19730
     5 XSWC,YSWC,GRID,LX,LY,A(2),B(2),POLNAM(3,2),CALNAM(7,2),          PMT19740
     6 ITA,IRD,IWR,IDSK,D80,D47,D8047,DIST,DELTA,HPRIME,                PMT19750
     7 ESH(2),PEAK,IBUOY,IRISE,IDWN,EFF,XS,UINV,WVEC,                   PMT19760
     8 NAS,NPS,INDEX,IGRID,IAV,ISCEN,IWDOPT,IWD,ISC,IPS,                PMT19770
     9 NTOPT,NWDOPT,NWSOPT,NWPOPT,NSCEN,NLIST,NARRAY,NTAPE,NCSOPT,      PMT19780
     * NMAX,NSTDWN,NPRISE,NINPEN,INTER,NPRINT,NGPR,NBID                 PMT19790
C                                                                       PMT19800
      COMMON/CSWOR/NWORST(25,25,5,2),CWORST(25,25,5,2)                  PMT19810
      COMMON/PARM1/NPOL,VD1,W1,VD2,W2                                   PMT19820
      COMMON/PARM1A/ICT,TAUC,GAMMA                                      PMT19830
      COMMON/PARM2A/HAS,KSC,AA,BA,CA                                    PMT19840
      COMMON/PARM7A/HA,P1(6)                                            PMT19850
      COMMON/WND/HMIN,HMAX,UMIN,IUFLG                                   PMT19851
C                                                                       PMT19860
      DIMENSION NAME(2),WDINC(6),SUMAQ(2),SUMPQ(2),SUMAR(2),EAR(2),     PMT19870
     1 CWS(6)                                                           PMT19880
      DIMENSION DCR(24,2),NSC(24),NWD(24),NWS(24),ASCALE(2)             PMT19890
      DIMENSION XX(100)                                                 PMT19900
      DATA NAME/4H    ,4H    /                                          PMT19910
      DATA WDINC/1.5707963,0.7853982,0.5235988,0.2617994,               PMT19920
     1           0.1745329,0.08726646/                                  PMT19930
      DATA CWS/1.5,2.46,4.47,6.93,9.61,12.52/                           PMT19940
      DATA HMIN/10./,HMAX/200./,UMIN/1./,HA/10./                        PMT19941
C                                                                       PMT19950
      IF(INDEX.NE.0) GO TO 300                                          PMT19960
C                                                                       PMT19970
      ISTOP=0                                                           PMT19980
C                                                                       PMT19990
C  R E A D   A L L   I N P U T   D A T A .                              PMT20000
C                                                                       PMT20010
C **** READ FIRST CONTROL PARAMETER CARD (TITLE).                       PMT20020
C                                                                       PMT20030
      READ(IRD,800)TT                                                   PMT20040
      WRITE(IWR,900) TT                                                 PMT20050
C                                                                       PMT20060
C **** READ SECOND CONTROL PARAMETER CARD (OPTIONS).                    PMT20070
C                                                                       PMT20080
C     NTOPT  = AVERAGING TIME OPTION (1 OR 2 OR 3).                     PMT20090
C     NWDOPT = WIND DIRECTION INPUT OPTION (0 TO 7).                    PMT20100
C     NWSOPT = WIND SPEED INPUT OPTION (0 OR 1).                        PMT20110
C     NWPOPT = WIND PROFILE EXPONENTS INPUT OPTION (0 OR 1).            PMT20120
C     NSCEN  = NUMBER OF SCENARIOS (1 TO 24).                           PMT20130
C     NLIST  = OUTPUT OPTION: LISTS OF CONC AND SURF DEP FLUX (0 OR 1)  PMT20140
C     NARRAY = OUTPUT OPTION: MAPS OF CONC AND SURF DEP FLUX (0 TO 3)   PMT20150
C     NTAPE  = OUTPUT OPTION: TAPE OF CONC AND SURF DEP FLUX (0 OR 1)   PMT20160
C     NCSOPT = OUTPUT OPTION: POINT SOURCE CULPABILITY LIST (0 OR 1).   PMT20170
C     NMAX   = OUTPUT OPTION: MAXIMUM CONC. FOR EACH SCENARIO (0 OR 1). PMT20180
C     NSTDWN = STACK-TIP DOWNWASH CORRECTION OPTION (0 OR 1).           PMT20190
C     NPRISE = NEW PLUME RISE EQUATIONS OPTION (0 OR 1).                PMT20200
C     NINPEN = NEW PLUME PENETRATION METHODS OPTION (0 OR 1).           PMT20210
C     INTER  = RECEPTOR INTERVAL ON TAPE OUTPUT (1,2,---).              PMT20220
C     NPRINT = OUTPUT OPTION: POINT SOURCE PLUME RISE INFO (0 OR 1)     PMT20230
C     INPTSC = INPUT OPTN: POINT SOURCE DATA ON UNIT IRD OR IDSK (1 OR 2)PMT20240
C     NGPR = GRADUAL PLUME RISE OPTION NEAR PT. SOURCE (= 0),           PMT20241
C     NGPR = 1, THEN FINAL EFFECTIVE PLUME RISE AT ALL DISTANCES        PMT20242
C     NBID = BOUYANCY INDUCED DISPERSION (BID), (=0 NO BID, =1 YES)     PMT20243
C                                                                       PMT20250
      READ(IRD,805)NTOPT,NWDOPT,NWSOPT,NWPOPT,NSCEN,NLIST,NARRAY,       PMT20260
     1 NTAPE,NCSOPT,NMAX,NSTDWN,NPRISE,NINPEN,INTER,NPRINT,INPTSC,NGPR, PMT20270
     1 NBID                                                             PMT20271
C                                                                       PMT20280
      IF(NTOPT.GE.1 .AND  NTOPT.LE.3) GO TO 2                           PMT20290
      WRITE(IWR,660) NTOPT                                              PMT20300
      NTOPT=1                                                           PMT20310
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    2 IF(NWDOPT.LE.1) GO TO 6                                           PMT20320
      IF(NWDOPT.GT.7) GO TO 5                                           PMT20330
      IF(NTOPT.EQ.1 .OR. NWDOPT.LE.1) GO TO 6                           PMT20340
      WRITE(IWR,615)                                                    PMT20350
    5 NWDOPT=0                                                          PMT20360
    6 IF(NWSOPT.GT.1) NWSOPT=0                                          PMT20370
      IF(NWPOPT.GT.1) NWPOPT=0                                          PMT20380
      IF(NSCEN.EQ.0) NSCEN=1                                            PMT20390
      IF(NTOPT.EQ.3.AND.NSCEN.EQ.24) NTOPT=2                            PMT20400
      IF(NTOPT.EQ.2 .AND. NSCEN.NE.24) GO TO 500                        PMT20410
   10 IF(NSCEN.GT.24) GO TO 510                                         PMT20420
   20 IF(NLIST.EQ.0) GO TO 25                                           PMT20430
      IF(NLIST.GT.1) GO TO 22                                           PMT20440
      IF(NWDOPT.LE.1) GO TO 25                                          PMT20450
      WRITE(IWR,605)                                                    PMT20460
   22 NLIST=0                                                           PMT20470
   25 IF(NARRAY.GT.3) NARRAY=0                                          PMT20480
      IF(NTAPE.EQ.0) GO TO 40                                           PMT20490
      IF(NTAPE.GT.1) GO TO 30                                           PMT20500
      IF(NWDOPT.LE.1) GO TO 40                                          PMT20510
      WRITE(IWR,620)                                                    PMT20520
   30 NTAPE=0                                                           PMT20530
   40 IF(NCSOPT.EQ.0) GO TO 51                                          PMT20540
      IF(NCSOPT.GT.1) NCSOPT=0                                          PMT20550
      IF(NTOPT.EQ.1) GO TO 45                                           PMT20560
      NCSOPT=0                                                          PMT20570
      WRITE(IWR,625)                                                    PMT20580
   45 IF(NWDOPT.GT.1.AND.NSCEN.GT.1) GO TO 50                           PMT20590
      GO TO 51                                                          PMT20600
   50 NCSOPT=0                                                          PMT20610
      WRITE(IWR,635)                                                    PMT20620
   51 IF(NMAX.GT.1) NMAX=0                                              PMT20630
      IF(NSTDWN.GT.1) NSTDWN=0                                          PMT20640
      IF(NPRISE.GT.1) NPRISE=0                                          PMT20650
      IF(NINPEN.GT.1) NINPEN=0                                          PMT20660
      IF(INTER.EQ.0) INTER=1                                            PMT20670
      IF(NPRINT.GT.1) NPRINT=0                                          PMT20680
      IF(INPTSC.LT.1 .OR. INPTSC.GT.2) INPTSC=1                         PMT20690
C                                                                       PMT20700
C       SET LABEL FOR TIME AVERAGING                                    PMT20710
      IAV=1                                                             PMT20720
      IF(NTOPT.EQ.2) IAV=24                                             PMT20730
      IF (NTOPT.EQ.3) IAV=NSCEN                                         PMT20740
C                                                                       PMT20750
C  **** READ THIRD CONTROL PARAMETER CARD (GRID, DTDZ)                  PMT20760
C                                                                       PMT20770
C    XRSWC,YRSWC = COORDINATES OF SOUTHWEST CORNER OF RECEPTOR GRID (KM)PMT20780
C    LX          = NUMBER OF COLUMNS IN RECEPTOR GRID.                  PMT20790
C    LY          = NUMBER OF ROWS IN RECEPTOR GRID.                     PMT20800
C    GRID        = SPACING BETWEEN ROWS AND COLUMNS OF RECEPTOR GRID (KM) PMT20810
C                                                                       PMT20820
C    DTDZ(1&2)   = VERTICAL POTENTIAL TEMPERATURE GRADIENT              PMT20830
C                     FOR STABILITY CLASSES E & F.                      PMT20840
C                                                                       PMT20850
      READ(IRD,810)XRSWC,YRSWC,LX,LY,GRID,DTDZ(1),DTDZ(2)               PMT20860
C                                                                       PMT20870
      IF(LX.EQ.0) LX=1                                                  PMT20880
      IF(LY.EQ.0) LY=1                                                  PMT20890
      IF(NTAPE.EQ.0) GO TO 115                                          PMT20900
C                                                                       PMT20910
      NRECS=((LX+1)/INTER)*((LY+1)/INTER)*NSCEN                         PMT20920
      IF(NTOPT.EQ.2) NRECS= NRECS/24                                    PMT20930
      IF(NTOPT.EQ.3) NRECS= NRECS/NSCEN                                 PMT20940
      IF(NRECS.LT.62500) GO TO 115                                      PMT20950
      WRITE(IWR,600)                                                    PMT20960
      NTAPE=0                                                           PMT20970
115   CONTINUE                                                          PMT20980
C                                                                       PMT20990
C  **** READ FOURTH CONTROL PARAMETER CARD (POLLUTANTS)                 PMT21000
C                                                                       PMT21010
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C     NPOL  = NUMBER OF POLLUTANTS (1 OR 2)                                PMT21020
C     ICT   = CHEMICAL TRANSFORMATION OR DECAY OPTION (0 OR 1)             PMT21030
C     VD1   = DEPOSITION VELOCITY FOR POLLUTANT SPECIES-1 (CM/S)           PMT21040
C     W1    = SETTLING VELOCITY FOR POLLUTANT SPOECIES-1 (CM/S)            PMT21050
C     VD2   = DEPOSITION VELOCITY FOR POLLUTANT SPECIES-2 (CM/S)           PMT21060
C     W2    = SETTLING VELOCITY FOR POLLUTANT SPECIES-2 (CM/S)             PMT21070
C     XKT   = CHEMICAL TRANSFORMATION OR DECAY RATE OF POLLUTANT           PMT21080
C             SPECIES-1 (PERCENT PER HOUR)                                 PMT21090
C     GAMMA = RATIO OF MOLECULAR WEIGHTS OF SPECIES-2 (PRODUCT)            PMT21100
C              TO SPECIES-1 (REACTANT) IN CHEMICAL TRANSFORMATION          PMT21110
C                                                                          PMT21120
C   NOTE: FOR DEPOSITION TO OCCUR, W SHOULD BE LESS THAN OR EQUAL TO VD.   PMT21130
C         FOR DEPOSITION OF GASES AND VERY SMALL PARTICLES, W=0.           PMT21140
C         FOR DEPOSITION OF SMALL PARTICLES, W IS LESS THAN VD.            PMT21150
C         FOR DEPOSITION OF PARTICLES OF SIZE > 50 MICRONS, W=VD.          PMT21160
C                                                                          PMT21170
      READ (IRD,812) NPOL,ICT,VD1,W1,VD2,W2,XKT,GAMMA                      PMT21180
C                                                                          PMT21190
      IF(NPOL.LT.1 .OR. NPOL.GT.2) NPOL=1                                  PMT21200
      IF(W1.GT.VD1) W1=VD1                                                 PMT21210
      IF(W1.LT.0.01) W1=0.0                                                PMT21220
      IF(VD1.LT.0.01) VD1=0.0                                              PMT21230
      IF(NPOL.EQ.2) GO TO 117                                              PMT21240
      VD2=0.0                                                              PMT21250
      W2=0.0                                                               PMT21260
      GO TO 118                                                            PMT21270
  117 IF(W2.GT.VD2) W2=VD2                                                 PMT21280
      IF(W2.LT.0.01) W2=0.0                                                PMT21290
      IF(VD2.LT.0.01) VD2=0.0                                              PMT21300
  118 IF(ICT.EQ.1) GO TO 119                                               PMT21310
      XKT=0.0                                                              PMT21320
      GAMMA=0.0                                                            PMT21330
      GO TO 122                                                            PMT21340
  119 IF(XKT.GE.0.1 .AND. XKT.LE.100.) GO TO 120                           PMT21350
      TXKT=0.1                                                             PMT21360
      IF(XKT.GT.100.) TXKT=100.                                            PMT21370
      WRITE(IWR,640) XKT,TXKT                                              PMT21380
      XKT=TXKT                                                             PMT21390
C                                                                          PMT21400
C    CONVERT CHEMICAL TRANSFORMATION RATE XKT (PERCENT PER HOUR) TO        PMT21410
C     THE EQUIVALENT TIME SCALE TAUC (SECONDS).                            PMT21420
  120 TAUC=0.36E06/XKT                                                     PMT21430
C                                                                          PMT21440
  122 IF(NCSOPT.EQ.0 .OR. (LX.LE.25 .AND. LY.LE.25)) GO TO 125             PMT21450
      WRITE(IWR,645)                                                       PMT21460
      NCSOPT=0                                                             PMT21470
C                                                                          PMT21480
C     SHIFT THE RECEPTOR GRID TO THE COMPUTATION GRID.                     PMT21490
125   XSWC= XRSWC - 0.5*GRID                                               PMT21500
      YSWC= YRSWC - 0.5*GRID                                               PMT21510
C                                                                          PMT21520
130   IF(DTDZ(1).LT.0.00001) DTDZ(1)=0.020                                 PMT21530
      IF(DTDZ(2).LT.0.00001) DTDZ(2)=0.035                                 PMT21540
C                                                                          PMT21550
C  IF GRID IS ZERO, SWITCH ON AUTOMATIC GRID OPTION.                       PMT21560
      IGRID=0                                                              PMT21570
      IF(GRID.LT.1.0E-5) IGRID=1                                           PMT21580
      IF(IGRID.EQ.1.AND.NTOPT.GT.1) GO TO 520                              PMT21590
C                                                                          PMT21600
C **** READ 5TH CONTROL PARAMETER CARD (AREA SOURCE EMISSIONS HEIGHT       PMT21610
C                          AND SCALING  , AND CONCENTRATION CALIBRATION)   PMT21620
C                                                                          PMT21630
C     HAS          = EFFECTIVE HEIGHT OF AREA SOURCE EMISSIONS (METERS).   PMT21640
C     ASCALE(1&2) = AREA SOURCE EMISSION SCALING FACTORS                   PMT21650
C                      FOR POLLUTANT SPECIES-1 AND 2.                      PMT21660
C     A(1&2)       = CONCENTRATION CALIBRATION FACTOR (INTERCEPT)          PMT21670
C                      FOR POLLUTANT SPECIES-1 AND 2.                      PMT21680
C     B(1&2)       = CONCENTRATION CALIBRATION FACTOR (SLOPE)              PMT21690
C                      FOR POLLUTANT SPECIES-1 AND 2.                      PMT21700
C                                                                          PMT21710
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  135 READ(IRD,815) HAS,ASCALE(1),ASCALE(2),A(1),B(1),A(2),B(2)         PMT21720
C                                                                       PMT21730
      IF(ASCALE(1).LE.0.) ASCALE(1)=1.0                                 PMT21740
      IF(ASCALE(2).LE.0.) ASCALE(2)=1.0                                 PMT21750
C                                                                       PMT21760
C  **** READ CARD 6 (POLLUTANT AND CALIBRATION LABELS)                  PMT21770
C                                                                       PMT21780
      READ(IRD,817)(POLNAM(I,1),I=1,3),(CALNAM(I,1),I=1,7),             PMT21790
     1             (POLNAM(I,2),I=1,3),(CALNAM(I,2),I=1,7)              PMT21800
C                                                                       PMT21810
      IF(NWPOPT.EQ.0) GO TO 136                                         PMT21820
C  **** READ CARD 7 (WIND PROFILE EXPONENTS AND ANEMOMETER HEIGHT)      PMT21830
C  NOTE: THIS IS AN OPTIONAL CARD                                       PMT21840
C                                                                       PMT21850
C     HA          = ANEMOMETER HEIGHT (METERS)                          PMT21860
C     P1(I),I=1,6 = WIND PROFILE EXPONENTS FOR STABILITY CLASSES 1 TO 6 PMT21870
C     HMIN        = WIND CONSTANT BELOW THIS HEIGHT (DEFAULT 10 M)      PMT21871
C     HMAX        = WIND CONSTANT ABOVE THIS HEIGHT (DEFAULT 200M)      PMT21872
C     UMIN  = WIND SPEED NOT ALLOWED LESS THEN THIS VALUE (DEFAULT 1 M/S)PMT21873
      READ(IRD,818) HA, HMIN, HMAX, UMIN,(P1(I),I=1,6)                  PMT21880
C     CHECK FOR DEFAULTS AND SET THEM EQUAL TO STANDARD VALUES.         PMT21890
      IF(HA.LT.0.01) HA=10.                                             PMT21900
      IF(HMIN.LT.0.01) HMIN=10.                                         PMT21901
      IF(HMAX.LT.0.01) HMAX=200.                                        PMT21902
      IF(UMIN.LT.0.01) UMIN=1.                                          PMT21903
      DO 136 I=1,6                                                      PMT21910
      IF(P1(I).LT.0.01) P1(I)=P(I)                                      PMT21920
  136 CONTINUE                                                          PMT21930
C                                                                       PMT21940
C  **** READ ONE TO 24 SCENARIO PARAMETER CARDS.                        PMT21950
C                                                                       PMT21960
C     NSC        = STABILITY CLASS NUMBER (1 TO 6)                      PMT21970
C     NWS        = WIND SPEED CLASS NUMBER (1 TO 6)                     PMT21980
C     NWD        = WIND SECTOR NUMBER (1 TO 16)                         PMT21990
C     WS         = WIND SPEED (M/S)                                     PMT22000
C     WD         = WIND DIRECTION (DEGREES)                             PMT22010
C     TA         = AMBIENT TEMPERATURE (DEGREES CELSIUS)                PMT22020
C     HMIX       = MIXING HEIGHT (METERS)                               PMT22030
C     DTDZI      = POT.TEMP.GRADIENT IN ELEVATED STABLE LAYER (DEG.C/M) PMT22040
C                                                                       PMT22050
      DO 150 IS=1,NSCEN                                                 PMT22060
      READ(IRD,820)NSC(IS),NWS(IS),NWD(IS),WS(IS),WD(IS),TA(IS),        PMT22070
     1 HMIX(IS),DTDZI(IS)                                               PMT22080
C                                                                       PMT22090
      IF(NSC(IS).GE.1 .AND. NSC(IS).LE.6) GO TO 140                     PMT22100
      NUM=1                                                             PMT22110
      IF(NSC(IS).GT.6) NUM=6                                            PMT22120
      WRITE(IWR,535) IS,NSC(IS),NUM                                     PMT22130
      NSC(IS)=NUM                                                       PMT22140
  140 IF(NWSOPT.EQ.0) GO TO 142                                         PMT22150
      IF(NWS(IS).GE.1 .AND. NWS(IS).LE.6) GO TO 144                     PMT22160
      NUM=1                                                             PMT22170
      IF(NWS(IS).GT.6) NUM=6                                            PMT22180
      WRITE(IWR,545) IS,NWS(IS),NUM                                     PMT22190
      NWS(IS)=NUM                                                       PMT22200
      GO TO 144                                                         PMT22210
  142 IF(WS(IS).GT.0.) GO TO 144                                        PMT22220
      WRITE(IWR,565) IS,WS(IS)                                          PMT22230
      WS(IS)=1.0                                                        PMT22240
  144 IF(NWDOPT.NE.1) GO TO 146                                         PMT22250
      IF(NWD(IS).GE.1 .AND. NWD(IS).LE.16) GO TO 146                    PMT22260
      NUM=1                                                             PMT22270
      IF(NWD(IS).GT.16) NUM=16                                          PMT22280
      WRITE(IWR,555) IS,NWD(IS),NUM                                     PMT22290
      NWD(IS)=NUM                                                       PMT22300
  146 IF(HMIX(IS).LT.1.0E-5) HMIX(IS)= 9999.9                           PMT22310
      IF(NINPEN.EQ.0) GO TO 150                                         PMT22320
      IF(DTDZI(IS).LT.0.00001) DTDZI(IS)=0.010                          PMT22330
150   CONTINUE                                                          PMT22340
C                                                                       PMT22350
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C  PRINT INPUT CONTROL PARAMETERS                                       PMT22360
C                                                                       PMT22370
      IF(ISTOP.EQ.1) WRITE(IWR,900) TT                                  PMT22380
      WRITE(IWR,902) NTOPT                                              PMT22390
      WRITE(IWR,904) NWDOPT                                             PMT22400
      WRITE(IWR,906) NWSOPT                                             PMT22410
      WRITE(IWR,908) NSCEN                                              PMT22420
      IF(IGRID.EQ.0) WRITE(IWR,916) LX,LY,GRID,XRSWC,YRSWC              PMT22430
      WRITE(IWR,900) TT                                                 PMT22440
      WRITE(IWR,922) NPOL,(POLNAM(I,1),I=1,3)                           PMT22450
      IF(NPOL.EQ.2) WRITE(IWR,923) (POLNAM(I,2),I=1,3)                  PMT22460
      WRITE(IWR,924) ASCALE(1)                                          PMT22470
      IF(NPOL.EQ.2) WRITE(IWR,935) ASCALE(2)                            PMT22480
      WRITE(IWR,925) A(1),B(1)                                          PMT22490
      IF(NPOL.EQ.2) WRITE(IWR,926) A(2),B(2)                            PMT22500
      WRITE(IWR,927) (CALNAM(I,1),I=1,7)                                PMT22510
      IF(NPOL.EQ.2) WRITE(IWR,921) (CALNAM(I,2),I=1,7)                  PMT22520
      WRITE(IWR,928) VD1                                                PMT22530
      IF(NPOL.EQ.2) WRITE(IWR,931) VD2                                  PMT22540
      WRITE(IWR,929) W1                                                 PMT22550
      IF(NPOL.EQ.2) WRITE(IWR,933) W2                                   PMT22560
      WRITE(IWR,930) ICT                                                PMT22570
      IF(NPOL.EQ.1) WRITE(IWR,932)                                      PMT22580
      IF(NPOL.EQ.2) WRITE(IWR,934)                                      PMT22590
      IF(ICT.EQ.0) GO TO 152                                            PMT22600
      WRITE(IWR,936) XKT                                                PMT22610
      IF(NPOL.EQ.1) GO TO 152                                           PMT22620
      WRITE(IWR,938) GAMMA                                              PMT22630
  152 WRITE(IWR,940)                                                    PMT22640
      IF(NLIST.GT.0) WRITE(IWR,942) NLIST                               PMT22650
      IF(NARRAY.GT.0) WRITE(IWR,944) NARRAY                             PMT22660
      IF(NARRAY.EQ.1) WRITE(IWR,946)                                    PMT22670
      IF(NARRAY.EQ.2) WRITE(IWR,948)                                    PMT22680
      IF(NARRAY.EQ.3) WRITE(IWR,950)                                    PMT22690
      IF(NTAPE.GT.0) WRITE(IWR,952) NTAPE,INTER                         PMT22700
      IF(NMAX.GT.0) WRITE(IWR,958) NMAX                                 PMT22710
C                                                                       PMT22720
C    PRINT INPUT PARAMETERS FOR SCENARIOS                               PMT22730
C                                                                       PMT22740
      WRITE(IWR,960)TT                                                  PMT22750
      WRITE(IWR,962)                                                    PMT22760
      WRITE(IWR,963)                                                    PMT22770
      WRITE(IWR,964)                                                    PMT22780
C                                                                       PMT22790
      DO 162 IS=1,NSCEN                                                 PMT22800
      KS=NSC(IS)                                                        PMT22810
      WRITE(IWR,966) IS,SCLAB(KS)                                       PMT22820
      IF(NWSOPT.EQ.0) GO TO 153                                         PMT22830
      KW=NWS(IS)                                                        PMT22840
      WS(IS)=CWS(KW)                                                    PMT22850
      WRITE(IWR,970) KW                                                 PMT22860
      GO TO 154                                                         PMT22870
  153 WRITE(IWR,972) WS(IS)                                             PMT22880
  154 IF(NWDOPT.EQ.1) GO TO 155                                         PMT22890
      WDOUT=WD(IS)                                                      PMT22900
      WRITE(IWR,973) WDOUT                                              PMT22910
      GO TO 156                                                         PMT22920
  155 KD=NWD(IS)                                                        PMT22930
      WDOUT=SECTAN(KD) * 180./3.14159265                                PMT22940
      WRITE(IWR,974) KD                                                 PMT22950
  156 IF(NINPEN.EQ.1)WRITE(IWR,978)TA(IS),DTDZI(IS),HMIX(IS)            PMT22960
      IF(NINPEN.EQ.0)WRITE(IWR,979) TA(IS),HMIX(IS)                     PMT22970
      WD(IS)= WD(IS)*3.14159265/180.                                    PMT22980
      TA(IS)= TA(IS) + 273.15                                           PMT22990
C                                                                       PMT23000
C  FOR EACH SCENARIO, CALCULATE THE CRITICAL DOWNWIND DISTANCES         PMT23010
C    AT WHICH VERTICAL MIXING IMPENDS (DCRIT(IS,1)) AND IS COMPLETE   PMT23020
C    (DCRIT(IS,2)).                                                     PMT23030
      JSC=NSC(IS)                                                       PMT23040
      PC1=0.47*HMIX(IS)/AZ(JSC)                                         PMT23050
      IF(JSC.NE.3) GO TO 157
C
C  STABILITY CLASS C
      DCR(IS,1)=.001*PC1
      GO TO 161
  157 IF(JSC.LT.3) GO TO 158
C
C  STABILITY CLASSES D,E, AND F
      PC2=PC1*PC1*BZ(JSC)
      PC3=2./(PC1*BZ(JSC))
      DUMMY= 0.5*PC2*(1.+SQRT(1.+PC3*PC3))
      DCR(IS,1)=.001*DUMMY
      GO TO 161
C
C  STABILITY CLASSES A AND B
C  FIRST APPROXIMATION
  158 XX(1)=PC1
      DO 159 I=1,100
      I1=I+1
      XX(I1)=PC1/SQRT(1.+BZ(JSC)*XX(I))
      DIFF=ABS(XX(I1)-XX(I))
      IF(DIFF.LE.0.5) GO TO 160
  159 CONTINUE
  160 DCR(IS,1)=.001*XX(I1)
  161 DCR(IS,2)=2.*DCR(IS,1)
162   CONTINUE
C
C  **** READ UP TO 50 AREA SOURCE CARDS.
C
C     XA,YA    = COORDINATES OF SOUTHWEST CORNER OF AREA SOURCE (KM).
C     SIZE     = LENGTH OF A SIDE OF AREA SOURCE (M).
C     EA(1&2)  = EMISSION RATES OF 2 POLLUTANTS (G/S).
C      NOTE THAT EA(1&2) ARE EMISSION RATES OF AN EQUIVALENT POINT
C      SOURCE LOCATED AT THE CENTER OF THE AREA SOURCE.
C
      WRITE(IWR,990) TT
      NAS=1
      SUMAQ(1)=0.
      SUMAQ(2)=0.
      SUMAR(1)=0.
      SUMAR(2)=0.
C
170   READ(IRD,825)XA(NAS),YA(NAS),SIZE(NAS),EA(NAS,1),EA(NAS,2)
C
      IF(NPOL.EQ.1) EA(NAS,2)=0.0
      IF((SIZE(NAS)+EA(NAS,1)+EA(NAS,2)).LT.1.0E-04) GO TO 180
      IF(SIZE(NAS).GE.1.0) GO TO 172
      SIZE(NAS)=1.0
      IF(GRID.NE.0.) SIZE(NAS)=GRID*1000.
      WRITE(IWR,585) NAS,SIZE(NAS)
  172 DO 175 K=1,2
      EAR(K)=EA(NAS,K)
      SUMAR(K)=SUMAR(K)+EAR(K)
      EA(NAS,K)= EA(NAS,K)*ASCALE(K)
175   SUMAQ(K)=SUMAQ(K)+EA(NAS,K)
C
C   PRINT INPUT PARAMETERS FOR THIS AREA SOURCE
      WRITE(IWR,992)NAS,XA(NAS),YA(NAS),SIZE(NAS),EAR(1),EA(NAS,1),
     1EAR(2),EA(NAS,2)
C
      SIZE(NAS)=SIZE(NAS)*0.001
      IF(NAS/50*50.EQ.NAS) WRITE(IWR,990)TT
      NAS=NAS+1
      GO TO 170
180   NAS=NAS-1
      WRITE(IWR,994) SUMAR(1),SUMAQ(1),SUMAR(2),SUMAQ(2)
      WRITE(IWR,996) HAS
C
C
C  **** READ UP TO 300 POINT SOURCES
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C                                                                       PMT23760
C     XP,YP   = COORDINATES OF POINT SOURCE (KM).                       PMT23770
C     EP(1&2) = EMISSION RATES OF 2 POLLUTANTS (G/S).                   PMT23780
C     HP      = SOURCE HEIGHT (M).                                      PMT23790
C     DP      = INSIDE DIAMETER (M).                                    PMT23800
C     VP      = VELOCITY (M/S).                                         PMT23810
C     TP      = TEMPERATURE (DEGREES CELSIUS).                          PMT23820
C     NAME    = IDENTIFICATION.                                         PMT23830
C                                                                       PMT23840
  184 WRITE(IWR,980) TT                                                 PMT23850
      NPS=1                                                             PMT23860
      SUMPQ(1)=0.                                                       PMT23870
      SUMPQ(2)=0.                                                       PMT23880
C                                                                       PMT23890
  185 IF(INPTSC.EQ.2)READ(IDSK,830)XP(NPS),YP(NPS),EP(NPS,1),EP(NPS,2), PMT23900
     1 HP(NPS),DP(NPS),VP(NPS),TP(NPS),NAME(1),NAME(2)                  PMT23910
      IF(INPTSC.EQ.1) READ(IRD,830)XP(NPS),YP(NPS),EP(NPS,1),EP(NPS,2), PMT23920
     1 HP(NPS),DP(NPS),VP(NPS),TP(NPS),NAME(1),NAME(2)                  PMT23930
C                                                                       PMT23940
      IF(NPOL.EQ.1) EP(NPS,2)=0.0                                       PMT23950
      IF(HP(NPS)+DP(NPS)+VP(NPS)+TP(NPS).LT.1.0E-4) GO TO 190           PMT23960
      IF(DP(NPS).GT.0.0) GO TO 187                                      PMT23970
      WRITE(IWR,575) NPS                                                PMT23980
      DP(NPS)=1.0E-4                                                    PMT23990
C                                                                       PMT24000
C  PRINT INPUT PARAMETERS FOR THIS POINT SOURCE                         PMT24010
  187 WRITE(IWR,984) NPS,NAME(1),NAME(2),XP(NPS),YP(NPS),EP(NPS,1),     PMT24020
     1 EP(NPS,2),HP(NPS),DP(NPS),VP(NPS),TP(NPS)                        PMT24030
C                                                                       PMT24040
      TP(NPS)=TP(NPS)+273.15                                            PMT24050
      IF(NPS/50*50.EQ.NPS) WRITE(IWR,980)TT                             PMT24060
      SUMPQ(1)=SUMPQ(1)+EP(NPS,1)                                       PMT24070
      SUMPQ(2)=SUMPQ(2)+EP(NPS,2)                                       PMT24080
      NPS=NPS+1                                                         PMT24090
      GO TO 185                                                         PMT24100
190   NPS= NPS-1                                                        PMT24110
      WRITE(IWR,986) SUMPQ(1),SUMPQ(2)                                  PMT24120
C                                                                       PMT24130
      IF(NPS.LT.1) GO TO 192                                            PMT24140
      WRITE(IWR,901)                                                    PMT24150
      WRITE(IWR,907) NWPOPT                                             PMT24160
      IF(NWPOPT.EQ.1) WRITE(IWR,959) (P1(I),I=1,6),HA ,HMIN,HMAX,UMIN   PMT24170
      WRITE(IWR,910) NSTDWN                                             PMT24180
      WRITE(IWR,911) NPRISE                                             PMT24190
      WRITE(IWR,920) DTDZ(1),DTDZ(2)                                    PMT24200
      WRITE(IWR,912) NINPEN                                             PMT24210
      IF(IGRID.EQ.1) WRITE(IWR,914)                                     PMT24220
      IF(NCSOPT.GT.0.OR.NPRINT.GT.0) WRITE(IWR,940)                     PMT24230
      IF(NCSOPT.GT.0) WRITE(IWR,954) NCSOPT                             PMT24240
      IF(NPRINT.GT.0) WRITE(IWR,956) NPRINT                             PMT24250
      IF(NGPR.EQ.0) WRITE(IWR,915) NGPR                                 PMT24251
      IF(NGPR.EQ.1) WRITE(IWR,919) NGPR                                 PMT24252
915   FORMAT(' ',10X,'GRAD. PLUME RISE OPTION WHEN NGPR=0 : NGPR = ',I1)PMT24253
919   FORMAT(' ',10X,' FINAL EFFECTIVE PLUME RISE USED: NGPR =',I1)     PMT24254
      WRITE(IWR,918) NBID                                               PMT24255
918   FORMAT(' ',9X,'BOUYANCY INDUCED DISPERSION FOR NBID=1: NBID=',I2) PMT24256
C                                                                       PMT24260
C     IF THERE WERE SERIOUS ERRORS IN INPUT PARAMETERS, STOP            PMT24270
  192 IF(ISTOP.EQ.0) GO TO 195                                          PMT24280
      WRITE(IWR,630)                                                    PMT24290
      CALL WAUDIT
      STOP                                                              PMT24300
C                                                                       PMT24310
C    INITIALIZE FOR FIRST CALL TO INMOD FOR SCENARIO PREPARATION        PMT24320
  195 IWDOPT= 0                                                         PMT24330
      ISCEN=0                                                           PMT24340
      RETURN                                                            PMT24350
C                                                                       PMT24360
C                                                                       PMT24370
C  P R E P A R E   S C E N A R I O   I N F O R M A T I O N .            PMT24380
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C                                                                       PMT24390
300   IF(NWDOPT.LE.1) GO TO 350                                         PMT24400
      IF(ISCEN.EQ.0.OR.IWDOPT.GE.4) GO TO 320                           PMT24410
      IWDOPT= IWDOPT + 1                                                PMT24420
      WD(ISCEN)= WD(ISCEN) + WDINC(NWDOPT-1)                            PMT24430
      IF(WD(ISCEN).GE.6.2831853) WD(ISCEN)=WD(ISCEN) - 6.2831853        PMT24440
      GO TO 353                                                         PMT24450
320   ISCEN= ISCEN + 1                                                  PMT24460
      IWDOPT= 1                                                         PMT24470
      GO TO 353                                                         PMT24480
350   ISCEN= ISCEN + 1                                                  PMT24490
353   ISC=NSC(ISCEN)                                                    PMT24500
      IWD=NWD(ISCEN)                                                    PMT24510
      D47= DCR(ISCEN,1)                                                 PMT24520
      D80= DCR(ISCEN,2)                                                 PMT24530
      D8047= D80 - D47                                                  PMT24540
      IF(NCSOPT.EQ.0) GO TO 400                                         PMT24550
      DO 380 I=1,25                                                     PMT24560
      DO 380 J=1,25                                                     PMT24570
      DO 380 K=1,5                                                      PMT24580
      DO 380 N=1,2                                                      PMT24590
      NWORST(I,J,K,N)=0                                                 PMT24600
380   CWORST(I,J,K,N)=0.                                                PMT24610
400   RETURN                                                            PMT24620
C                                                                       PMT24630
C   ERROR MESSAGES                                                      PMT24640
C                                                                       PMT24650
  500 WRITE(IWR,505)                                                    PMT24660
  505 FORMAT(1H0,'WHEN TIME AVG OPTION NTOPT=2, NUMBER OF SCENARIOS MUSTPMT24670
     1 =24')                                                            PMT24680
      ISTOP=1                                                           PMT24690
      GO TO 10                                                          PMT24700
  510 WRITE(IWR,515) NSCEN                                              PMT24710
  515 FORMAT(1H0,'MAXIMUM NUMBER OF SCENARIOS ALLOWED IS 24. NSCEN=',I4)PMT24720
      ISTOP=1                                                           PMT24730
      GO TO 20                                                          PMT24740
  520 WRITE(IWR,525)                                                    PMT24750
  525 FORMAT(1H0,'AUTOGRID MAY NOT BE USED WITH TIME AVG OPTION NTOPT>1'PMT24760
     1)                                                                 PMT24770
      ISTOP=1                                                           PMT24780
      GO TO 135                                                         PMT24790
  535 FORMAT(1H0,'IN SCENARIO',I3,' STABILITY CLASS NUMBER NSC=',I2,    PMT24800
     1' IS OUT OF RANGE.  NSC SET TO',I2)                               PMT24810
  545 FORMAT(1H0,'IN SCENARIO',I3,' WIND SPEED CLASS NUMBER NWS=',I2,   PMT24820
     1' IS OUT OF RANGE.  NWS SET TO',I2)                               PMT24830
  555 FORMAT(1H0,'IN SCENARIO',I3,' WIND DIRECTION SECTOR NUMBER NWD=', PMT24840
     1 I3,' IS OUT OF RANGE.  NWD SET TO',I3)                           PMT24850
  565 FORMAT(1H0,'IN SCENARIO',I3,' SPECIFIED WIND SPEED WS =',F7.3,' ISPMT24860
     1 LESS THAN ZERO.  WS SET TO 1.0 M/S')                             PMT24870
  575 FORMAT(1H0,'POINT SOURCE',I4,':  INSIDE DIAMETER MUST BE GREATER TPMT24880
     1HAN ZERO.  DP SET TO .0001 M')                                    PMT24890
  585 FORMAT(1H0,'AREA SOURCE',I3,':  LENGTH OF SIDE MUST BE GREATER THAPMT24900
     1N ZERO.  SIZE SET TO ',F9.2)                                      PMT24910
  600 FORMAT(1H0,'RUN REQUESTED WOULD PRODUCE OVER 62500 RECORDS ON TAPEPMT24920
     1'/' OUTPUT OPTION NTAPE HAS BEEN SET TO ZERO')                    PMT24930
  605 FORMAT(1H0,'OUTPUT OPTION NLIST MAY NOT BE USED WITH AUTOMATIC WINPMT24940
     1D SHIFT OPTION (NWDOPT>1)'/' NLIST HAS BEEN SET TO ZERO')         PMT24950
  615 FORMAT(1H0,'AUTOMATIC WIND SHIFT OPTION (NWDOPT>1) MAY NOT BE USEDPMT24960
     1 WITH TIME AVG OPTION NTOPT>1'/' NWDOPT HAS BEEN SET TO ZERO')    PMT24970
  620 FORMAT(1H0,'OUTPUT OPTION NTAPE MAY NOT BE USED WITH AUTOMATIC WINPMT24980
     1D SHIFT OPTION (NWDOPT>1)'/' NTAPE HAS BEEN SET TO ZERO')         PMT24990
  625 FORMAT(1H0,'CONTROL STRATEGY OUTPUT OPTION NCSOPT MAY NOT BE USED PMT25000
     1WITH NTOPT>1'/' NCSOPT HAS BEEN SET TO ZERO')                     PMT25010
  630 FORMAT(1H1//' SERIOUS ERROR(S) IN INPUT PARAMETERS',5X,           PMT25020
     1 'RUN CANNOT BE CONTINUED')                                       PMT25030
  635 FORMAT(1H0,'CONTROL STRATEGY OUTPUT OPTION NCSOPT MAY NOT BE USED PMT25040
     1FOR MORE THAN'/' ONE SCENARIO WITH AUTOMATIC WINDSHIFT OPTION'/,  PMT25050
     2' NCSOPT HAS BEEN SET TO ZERO')                                   PMT25060
  640 FORMAT(1H0,'CHEMICAL TRANSFORMATION RATE XKT=',F7.3,' IS OUT OF RAPMT25070
     1NGE'/' XKT HAS BEEN SET TO',F8.3)                                 PMT25080
  645 FORMAT(1H0,'CONTROL STRATEGY OUTPUT OPTION NCSOPT MAY NOT BE USED PMT25090
     1WHEN NUMBER OF COLUMNS OR ROWS IN RECEPTOR GRID IS GREATER THAN 25PMT25100
     2'/' NCSOPT HAS BEEN SET TO ZERO')                                 PMT25110
  660 FORMAT(1H0,'TIME AVERAGING OPTION NTOPT=',I2,' IS OUT OF RANGE.  NPMT25120
     1TOPT SET TO 1')                                                   PMT25130
C                                                                       PMT25140
C   INPUT FORMATS                                                       PMT25150
C                                                                       PMT25160
800   FORMAT(20A4)                                                      PMT25170
805   FORMAT(18I4)                                                      PMT25180
810   FORMAT(2F10.0,2I10,3F10.0)                                        PMT25190
812   FORMAT(2I5,6F10.0)                                                PMT25200
815   FORMAT(7F10.0)                                                    PMT25210
817   FORMAT(3A4,7A4,3A4,7A4)                                           PMT25220
818   FORMAT(10F7.0)                                                    PMT25230
820   FORMAT(3I5,5F10.0)                                                PMT25240
825   FORMAT(5F10.0)                                                    PMT25250
830   FORMAT(8F9.0,2A4)                                                 PMT25260
C                                                                       PMT25270
C   OUTPUT FORMATS                                                      PMT25280
C                                                                       PMT25290
  900 FORMAT(1H1,37X,'POLLUTION EPISODIC MODEL (PEM-2)'///4X,'INPUT CONTPMT25300
     1ROL PARAMETERS:  ',20A4//)                                        PMT25310
  901 FORMAT(//4X,'INPUT CONTROL PARAMETERS:'//)                        PMT25320
  902 FORMAT(10X,'AVERAGING TIME OPTION: NTOPT=',I1//                   PMT25330
     1 18X,'A SCENARIO IS A SET OF METEOROLOGICAL DATA FOR ONE HOUR'//  PMT25340
     2 13X,'1  1 HOUR: CONCENTRATIONS ARE CALCULATED FOR EACH SCENARIO'/PMT25350
     3 13X,'2  24 HOURS: CONCENTRATIONS CALCULATED FOR 24 SCENARIOS ARE PMT25360
     4AVERAGED'/13X,'3  VARIABLE: CONCENTRATIONS CALCULATED FOR A GIVEN PMT25370
     5NUMBER (2 TO 23) OF SCENARIOS ARE AVERAGED'//)                    PMT25380
  904 FORMAT(10X,'WIND DIRECTION OPTION: NWDOPT=',I1//                  PMT25390
     113X,'0  DIRECTION IN DEGREES TO BE SPECIFIED FOR EACH SCENARIO'/  PMT25400
     213X,'1  SECTOR NUMBER TO BE SPECIFIED FOR EACH SCENARIO'/         PMT25410
     312X,'2-7 DIRECTION IN DEGREES TO BE SPECIFIED FOR THE FIRST OF FOUPMT25420
     4R SUB-SCENARIOS.'/17X,'FOR EACH SUCCEEDING SUB-SCENARIO, WIND DIREPMT25430
     5CTION IS AUTOMATICALLY INCREASED'/17X,'BY 90,45,30,15,10,OR 5 DEGRPMT25440
     6EES, DEPENDING ON THE OPTION NUMBER SELECTED.'//)                 PMT25450
  906 FORMAT(10X,'WIND SPEED OPTION: NWSOPT=',I1//                      PMT25460
     113X,'0  SPEED IN M/S TO BE SPECIFIED FOR EACH SCENARIO'/          PMT25470
     213X,'1  WIND SPEED CLASS NUMBER TO BE SPECIFIED FOR EACH SCENARIO'PMT25480
     3//)                                                               PMT25490
  907 FORMAT(10X,'WIND PROFILE EXPONENTS OPTION: NWPOPT=',I1//          PMT25500
     113X,'0  EXPONENTS AND ANEMOMETER HEIGHT ARE STANDARD DEFAULT VALUEPMT25510
     2S'/                                                               PMT25520
     313X,'1  EXPONENTS AND ANEMOMETER HEIGHT TO BE SPECIFIED BY THE USEPMT25530
     4R')                                                               PMT25540
  908 FORMAT(10X,'NUMBER OF SCENARIOS: NSCEN=',I2//)                    PMT25550
  910 FORMAT(//10X,'STACK-TIP DOWNWASH ALGORITHM OPTION: NSTDWN=',I1//  PMT25560
     1 13X,'0  ALGORITHM IS IN EFFECT'/                                 PMT25570
     2 13X,'1  ALGORITHM IS NOT USED'//)                                PMT25580
  911 FORMAT(10X,'NEW PLUME-RISE EQUATIONS OPTION: NPRISE=',I1//        PMT25590
     1 13X,'0  STANDARD PLUME-RISE EQS. ARE USED FOR ALL STABILITY CLASSPMT25600
     2ES'/                                                              PMT25610
     3 13X,'1  NEW EQS. ARE USED FOR PEAK BUOYANCY RISE FOR STABILITY CLPMT25620
     4ASSES A-D'//)                                                     PMT25630
  912 FORMAT(10X,'PLUME PENETRATION ABOVE MIXING HEIGHT OPTION: NINPEN='PMT25640
     1,I1//,                                                            PMT25650
     2 13X,'0  STANDARD TREATMENT OF PLUME PENETRATION ABOVE THE MIXING'PMT25660
     3,' HEIGHT'/,                                                      PMT25670
     4 13X,'1  NEW SCHEMES FOR PLUME PENETRATION OF ELEVATED STABLE LAYEPMT25680
     5R USED'/16X,' FOR STABILITY CLASSES A-D AND BUOYANCY-DOMINATED PLUPMT25690
     6ME'//)                                                            PMT25700
  914 FORMAT(10X,'AUTOMATIC RECEPTOR GRID OPTION IS IN EFFECT'//)       PMT25710
  916 FORMAT(10X,'RECEPTOR GRID:',                                      PMT25720
     16X,'COLUMNS: LX=',I3,4X,'ROWS: LY=',I3/                           PMT25730
     230X,'SPACING: GRID=',F7.3,' KM'/                                  PMT25740
     330X,'SOUTHWEST CORNER    XRSWC= ',F8.3,' KM W'/                   PMT25750
     450X,'YRSWC= ',F8.3,' KM S'//)                                     PMT25760
  920 FORMAT(10X,'POTENTIAL TEMPERATURE GRADIENT: DTDZ(1)= ',F7.3,      PMT25770
     1' DEG/M    STABILITY CLASS E'/                                    PMT25780
     242X,'DTDZ(2)= ',F7.3,' DEG/M    STABILITY CLASS F'//)             PMT25790
  921 FORMAT(1H+,85X,7A4)                                               PMT25800
  922 FORMAT(10X,'NUMBER OF POLLUTANTS: NPOL=',I1/                      PMT25810
     1 51X,'POLLUTANT-1: ',3A4)                                         PMT25820
  923 FORMAT(1H+,85X,'POLLUTANT-2: ',3A4)                               PMT25830
  924 FORMAT(/10X,'AREA SOURCE SCALING FACTOR:',17X,'ASCALE=',F9.3)     PMT25840
  925 FORMAT(10X,'CALIBRATION COEFFICIENTS:',                           PMT25850
     1 16X,'A=',F10.3,'   B=',F10.3)                                    PMT25860
  926 FORMAT(1H+,85X,'A=',F10.3,'   B=',F10.3)                          PMT25870
  927 FORMAT(10X,'CALIBRATION IDENTIFICATION:',14X,7A4,6X,7A4)          PMT25880
  928 FORMAT(10X,'DEPOSITION VELOCITY (CM/S):',20X,'VD1=',F8.3)         PMT25890
  929 FORMAT(10X,'SETTLING VELOCITY (CM/S):',23X,'W1=',F8.3)            PMT25900
  930 FORMAT(//10X,'CHEMICAL TRANSFORMATION OPTION: ICT=',I1/)          PMT25910
  931 FORMAT(1H+,91X,'VD2=',F8.3)                                       PMT25920
  932 FORMAT(13X,'NPOL=1'/                                              PMT25930
     215X,'ICT=0  CHEMICAL TRANSFORMATION LOSS OF POLLUTANT IS IGNORED'/PMT25940
     315X,'ICT=1  FIRST-ORDER CHEMICAL TRANSFORMATION LOSS OF POLLUTANT PMT25950
     4IS CONSIDERED'//)                                                 PMT25960
  933 FORMAT(1H+,92X,'W2=',F8.3)                                        PMT25970
  934 FORMAT(13X,'NPOL=2'/                                              PMT25980
     215X,'ICT=0  CHEMICAL TRANSFORMATION LOSS OF POLLUTANTS IS IGNORED'PMT25990
     3/15X,'ICT=1  FIRST-ORDER CHEMICAL TRANSFORMATION OF POLLUTANT-1 TOPMT26000
     4 POLLUTANT-2 IS CONSIDERED'//)                                    PMT26010
  935 FORMAT(1H+,88X,'ASCALE=',F9.3)                                    PMT26020
  936 FORMAT(10X,'CHEMICAL TRANSFORMATION OR DECAY RATE: XKT=',F7.3,    PMT26030
     1' PERCENT/HR'/)                                                   PMT26040
  938 FORMAT(10X,'RATIO OF MOLECULAR WEIGHTS OF POLLUTANT-2 (PRODUCT) TOPMT26050
     1 POLLUTANT-1 (REACTANT): GAMMA=',F6.3/)                           PMT26060
  940 FORMAT(10X,'OUTPUT OPTIONS SELECTED:'//)                          PMT26070
  942 FORMAT(13X,'NLIST=',I1,3X,'LISTS OF CONCENTRATION AND SURFACE DEPOPMT26080
     1SITION FLUX AT EACH RECEPTOR IN THE GRID,'/24X,'ONE COLUMN PER PAGPMT26090
     2E')                                                               PMT26100
  944 FORMAT(13X,'NARRAY=',I1,2X,'MAPS OF CONCENTRATION AND SURFACE DEPOPMT26110
     1SITION FLUX AT EACH RECEPTOR IN THE GRID,')                       PMT26120
  946 FORMAT(24X,'CALIBRATED AND UNCALIBRATED')                         PMT26130
  948 FORMAT(24X,'UNCALIBRATED ONLY')                                   PMT26140
  950 FORMAT(24X,'CALIBRATED ONLY')                                     PMT26150
  952 FORMAT(13X,'NTAPE=',I1,3X,'TAPE CONTAINING COORDINATES, CONCENTRATPMT26160
     1ION, AND SURFACE DEPOSITION FLUX'/24X,'AT EACH RECEPTOR IN THE GRIPMT26170
     2D'/13X,'INTER=',I2,2X,'INTERVAL OF RECEPTORS WHICH WILL BE WRITTENPMT26180
     3 ON TAPE')                                                        PMT26190
  954 FORMAT(13X,'NCSOPT=',I1,2X,'LIST OF POINT SOURCE CULPABILITY FOR CPMT26200
     1ONCENTRATION AND SURFACE DEPOSITION FLUX'/24X,'AT EACH RECEPTOR INPMT26210
     2 THE GRID'//)                                                     PMT26220
  956 FORMAT(13X,'NPRINT=',I1,2X,'LIST OF POINT SOURCE PARAMETERS AND EFPMT26230
     1FECTIVE STACK HEIGHTS'/24X,'PRINTED AT BEGINNING OF EACH SCENARIO'PMT26240
     2//)                                                               PMT26250
  958 FORMAT(13X,'NMAX=',I1,4X,'LIST OF RECEPTORS WITH HIGHEST CONCENTRAPMT26260
     1TION AND SURFACE DEPOSITION FLUX'/24X,'FOR EACH SCENARIO - PRINTEDPMT26270
     2 AT END OF RUN')                                                  PMT26280
  959 FORMAT(/16X,'USER SPECIFIED WIND PROFILE EXPONENT VALUES:'/20X,   PMT26290
     16(F4.2,3X)/20X,'ANEMOMETER HEIGHT = ',F4.1,1X,'METERS',           PMT26300
     23X,'HMIN =',1X,F4.1,' ,HMAX = ',F4.0,' ,UMIN = ',F3.1)            PMT26301
  960 FORMAT(1H1,37X,'POLLUTION EPISODIC MODEL (PEM-2)'///4X,'INPUT SCENPMT26310
     1ARIO PARAMETERS:  ',20A4//26X,'WIND DIRECTIONS',27X,'WIND SPEED CLPMT26320
     2ASSES',12X,'STABILITY CLASSES'/)                                  PMT26330
  962 FORMAT(10X,'SECTOR    DIRECTION',6X,'SECTOR    DIRECTION',9X,     PMT26340
     1'CLASS    SPEED     CLASS',15X,'CLASS'/                           PMT26350
     210X,'NUMBER',8X,'(DEG)',6X,'NUMBER',8X,'(DEG)',9X,'INDEX   (M/S)  PMT26360
     3 INTERVAL(KT)',9X,'INDEX   CLASS'//13X,'1     N',7X,'0.0',9X,'9   PMT26370
     4S',5X,'180.0'/13X,'2     NNE     22.5',8X,'10     SSW    202.5',11X,PMT26380
     5'1',6X,'1.50',7X,'0-3',16X,'1',7X,'A'/13X,'3     NE',5X,'45.0',8X, PMT26390
     6'11     SW     225.0',11X,'2',6X,'2.46',7X,'4-6',16X,'2',7X,'B')  PMT26400
  963 FORMAT(13X,'4     ENE     67.5',8X,'12     WSW    247.5',11X,'3',6X,PMT26410
     1'4.47',7X,'7-10',15X,'3',7X,'C'/13X,'5     E',6X,'90.0',8X,'13     WPMT26420
     2',5X,'270.0',11X,'4',6X,'6.93',6X,'11-16',15X,'4',7X,'D'/         PMT26430
     313X,'6     ESE    112.5',8X,'14     WNW    292.5',11X,'5',6X,'9.61',PMT26440
     46X,'17-21',15X.'5',7X,'E'/13X,'7     SE     135.0',8X,'15       ', PMT26450
     5 'NW    315.0',11X,'6',5X,'12.52    OVER 21',15X,'6',7X,'F'/      PMT26460
     613X,'8     SSE    157.5',8X,'16     NNW    337.5'///)             PMT26470
  964 FORMAT(5X,'SCENARIO',3X,'STABILITY',3X,'WIND SPEED',5X,'WIND',8X, PMT26480
     1'WIND',6X,'WIND',8X,'AMBIENT',4X,'TEMP GRADIENT ABOVE',8X,        PMT26490
     2'MIXING'/6X,'NUMBER',6X,'CLASS',7X,'CLASS',8X,'SPEED',6X,         PMT26500
     3'SECTOR',3X,'DIRECTION',3X,'TEMPERATURE',5X,'MIXING HEIGHT',      PMT26510
     411X,'HEIGHT'/43X,'(M/S)',17X,'(DEG)',7X,'(DEG C)',10X,            PMT26520
     5'(DEG/M)',15X,'(M)'/)                                             PMT26530
 966 FORMAT(8X,I2,10X,A2)                                               PMT26540
 970 FORMAT(1H+,31X,I1)                                                 PMT26550
 972 FORMAT(1H+,42X,F6.3)                                               PMT26560
 973 FORMAT(1H+,63X,F6.2)                                               PMT26570
 974 FORMAT(1H+,55X,I2)                                                 PMT26580
 978 FORMAT(1H+,76X,F7.2,11X,F6.3,11X,F7.1)                             PMT26590
 979 FORMAT(1H+,76X,F7.2,28X,F7.1)                                      PMT26600
 980 FORMAT(1H1,37X,'POLLUTION EPISODIC MODEL (PEM-2)'///4X,'INPUT POINPMT26610
     1T SOURCE PARAMETERS:  ',20A4///                                   PMT26620
     26X,'POINT SOURCE',10X,'COORDINATES',9X,'EMISSION RATE',           PMT26630
     36X,'EMISSION RATE',5X,'HEIGHT',4X,'DIAMETER',4X,'EXIT VEL',5X,    PMT26640
     4'EXIT TEMP'/5X,'NUMBER',3X,'LABEL',7X,'X(KM)',5X,'Y(KM)',6X,      PMT26650
     5'POLLUTANT-1 (G/S)',2X,'POLLUTANT-2 (G/S)',3X,'(M)',8X,'(M)',8X,  PMT26660
     6'(M/S)',8X,'(DEG C)'/)                                            PMT26670
 984 FORMAT(6X,I3,3X,2A4,3X,F8.2,2X,F8.2,10X,F9.3,10X,F9.3,6X,F6.2,5X, PMT26680
     1F6.3,6X,F7.3,6X,F8.3)                                             PMT26690
 986 FORMAT(1H0,5X,'SUMS OF THE POINT SOURCE EMISSION RATES',6X,F9.3,  PMT26700
     1' G/S',6X,F9.3,' G/S')                                            PMT26710
 990 FORMAT(1H1,37X,'POLLUTION EPISODIC MODEL (PEM-2)'///4X,'INPUT AREAPMT26720
     1 SOURCE PARAMETERS:  ',20A4///                                    PMT26730
     270X,'POLLUTANT-1',17X,'POLLUTANT-2'/5X,'AREA SOURCE',8X,          PMT26740
     3'COORDINATES',9X,'LENGTH OF SIDE',11X,'EMISSION RATE',15X,        PMT26750
     4'EMISSION RATE'/                                                  PMT26760
     57X,'NUMBER',9X,'X(KM)',5X,'Y(KM)',13X,'(M)',12X,'INPUT (G/S)',    PMT26770
     64X,'SCALED',7X,'INPUT (G/S)',4X,'SCALED'/)                        PMT26780
 992 FORMAT(9X,I2,8X,F8.2,2X,F8.2,10X,F8.2,9X,F9.3,4X,F9.3,6X,         PMT26790
     1 F9.3,4X,F9.3)                                                    PMT26800
 994 FORMAT(1H0,18X,'SUMS OF THE AREA SOURCE EMISSION RATES',          PMT26810
     1 7X,F9.3,4X,F9.3,6X,F9.3,4X,F9.3)                                 PMT26820
 996 FORMAT(/17X,'EFFECTIVE HEIGHT OF THE AREA SOURCE EMISSIONS',      PMT26830
     1 ' = ',F6.2,' M')                                                 PMT26840
      END                                                               PMT26850
C
C                                                                       PMT26860
C                                                                       PMT26870
      SUBROUTINE OUTMOD                                                 PMT26880
C                    SUBROUTINE OUTMOD , PART OF PEM-2 (VERSION 84130). PMT26890
C                                                                       PMT26900
C                                                                       PMT26910
C     SUBROUTINE OUTMOD COORDINATES OUTPUT OF THE CONCENTRATION(S)      PMT26920
C     AND SURFACE DEPOSITION FLUX(ES) CALCULATED FOR EACH RECEPTOR      PMT26930
C     IN THE GRID FOR EACH SCENARIO OR AVERAGING-PERIOD.                PMT26940
C     ON OPTION, THE OUTPUT MAY BE IN THE FORM OF LISTS, ARRAY          PMT26950
C     MAPS, OR TAPE.                                                    PMT26960
C     ON OPTION, OUTMOD CALLS SUBROUTINE WOROUT TO PRINT A CULPABILITY  PMT26970
C     LIST OF POINT SOURCES.                                            PMT26980
C     OUTMOD ALSO CALLS SUBROUTINE SCENMX TO DETERMINE AND STORE THE    PMT26990
C     RECEPTORS WITH MAXIMUM CONCENTRATION(S) AND SURFACE DEPOSITION    PMT27000
C     FLUX(ES) FOR THE AVERAGING-PERIOD.                                PMT27010
C                                                                       PMT27020
C                                                                       PMT27030
C *** PEM MODIFICATIONS AND FORMATS BY MARTHA M. STEVENS,               PMT27040
C     NOAA-ATDL, P.O. BOX-E, OAK RIDGE, TENN 37831                      PMT27050
C     DECEMBER 1982                                                     PMT27060
C *** PEM-2 MODIFICATIONS BY K. SHANKAR RAO                             PMT27070
C     DECEMBER 1984                                                     PMT27080
C                                                                       PMT27090
C                                                                       PMT27100
      COMMON/PEMCOM/CONC(50,50,2),SDF(50,50,2),TT(20),                  PMT27110
     1 XP(300),YP(300),EP(300,2),HP(300),DP(300),VP(300),TP(300),       PMT27120
     2 XA(50),YA(50),EA(50,2),SIZE(50),                                 PMT27130
     3 WD(24),WS(24),TA(24),HMIX(24),DTDZI(24),                         PMT27140
     4 AZ(6),BZ(6),CZ(6),P(6),SCLAB(6),DTDZ(2),SECTAN(16),              PMT27150
     5 XSWC,YSWC,GRID,LX,LY,A(2),B(2),POLNAM(3,2),CALNAM(7,2),          PMT27160
     6 ITA,IRD,IWR,IDSK,D80,D47,D8047,DIST,DELTA,HPRIME,                PMT27170
     7 ESH(2),PEAK,IBUOY,IRISE,IDWN,EFF,XS,UINV,WVEC,
     8 NAS,NPS,INDEX,IGRID,IAV,ISCEN,IWDOPT,IWD,ISC,IPS,
     9 NTOPT,NWDOPT,NWSOPT,NWPOPT,NSCEN,NLIST,NARRAY,NTAPE,NCSOPT,
     * NMAX,NSTDWN,NPRISE,NINPEN,INTER,NPRINT,NGPR,NBID
C
      COMMON/PARM1/NPOL,VD1,W1,VD2,W2
      DIMENSION CON(2),CALCON(2),SD(2),CALSD(2),AVD(2)
C
C
C     CONTROL STRATEGY RESULTS OUTPUT BY SUBROUTINE WOROUT
      IF(NCSOPT.GT.0) CALL WOROUT
C
C     PRINT AND/OR WRITE-ON-TAPE LISTS OF CONCENTRATION(S) AND
C     SURFACE DEPOSITION FLUX(ES)
      IF(NLIST.EQ.0 .AND. NTAPE.EQ.0) GO TO 350
      IF(NTAPE.GT.0) WRITE(ITA,900)TT
C
      NDEP=0
      IF(VD1.GE.0.01.OR.VD2.GE.0.01) GO TO 100
      GO TO 150
  100 NDEP=1
C     DEFINE CALIBRATION COEFFICIENTS FOR DEPOSITION FLUX
      AVD(1)=A(1)*VD1*36.
      AVD(2)=A(2)*VD2*36.
C
  150 IF(NLIST.EQ.0) GO TO 200
      WOUT=WD(ISCEN)*180./3.1415927
C     PRINT TITLE, SCENARIO, AND AVERAGING-PERIOD INFORMATION
      IF(NTOPT.EQ.1) WRITE(IWR,905)TT,ISCEN,SCLAB(ISC),WS(ISCEN),WOUT,
     1 HMIX(ISCEN),IAV
      IF(NTOPT.GT.1) WRITE(IWR,906) TT,ISCEN,IAV
C     PRINT TITLES FOR UNCALIBRATED CONCENTRATION AND DEPOSITION FLUX,
C     AND CALIBRATED CONCENTRATION
      WRITE(IWR,910)(CALNAM(L,1),L=1,7),(CALNAM(L,2),L=1,7)
C
C     BEGIN DO-LOOP ON RECEPTOR GRID COLUMNS
  200 DO 325 I=1,LX
      XI=I
      X=XSWC+(XI-0.5)*GRID
C
C     BEGIN DO-LOOP ON RECPTOR GRID ROWS
      DO 300 J=1,LY
      YJ=J
      Y=YSWC+(YJ-0.5)*GRID
C
C     INITIALIZE CONCENTRATION AND SDF VARIABLES
      DO 260 K=1,2
      CON(K)=0.
      CALCON(K)=0.
      SD(K)=0.
      CALSD(K)=0.
  260 CONTINUE
C
C     DEFINE AND PRINT UNCALIBRATED CONCENTRATIONS AND DEPOSITION FLUXES
C     AND CALIBRATED CONCENTRATIONS
      DO 280 K=1,NPOL
      CON(K)=CONC(I,J,K)
      CALCON(K)= A(K) + B(K) * CON(K)
      IF(NDEP.EQ.0) GO TO 280
      SD(K)=SDF(I,J,K)
      IF(NTAPE.GT.0) CALSD(K)= AVD(K) + B(K) * SD(K)
  280 CONTINUE
C
      IF(NLIST.EQ.0) GO TO 290
      IF(CON(1).LT.1.0.AND.CON(2).LT.1.0) GO TO 290
      WRITE(IWR,970) I,J,X,Y,CON(1),CON(2),SD(1),SD(2),
     1 CALCON(1),CALCON(2)
C
C     WRITE ON TAPE ALL CALIBRATED AND UNCALIBRATED OUTPUT DATA
  290 IF(NTAPE.EQ.0) GO TO 300
```

```
      IF(((I-1)/INTER)*INTER.NE.(I-1).OR.((J-1)/INTER)*INTER.NE.
     1 (J-1)) GO TO 300
      WRITE(ITA,975)X,Y,(CON(K),SD(K),CALCON(K),CALSD(K),K=1,2)
  300 CONTINUE
C
C     END LOOP ON GRID ROWS
  325 CONTINUE
C     END LOOP ON GRID COLUMNS
C
C
C     PRINT ARRAY MAPS OF CONCENTRATIONS
  350 IF(NARRAY.GT.0) CALL ARRAY
C
C  DETERMINE MAXIMUM PREDICTED CONCENTRATION(S) FOR SCENARIO VIA SCENMX
      IF(NMAX.GT.0.AND.(NTOPT.EQ.1.OR.ISCEN.EQ.NSCEN)) CALL SCENMX
C
      RETURN
C
  900 FORMAT(20A4)
  905 FORMAT(1H1,'PEM-2 OUTPUT:  PREDICTED CONCENTRATIONS:  ',
     120A4/' SCENARIO ',I2,', STABILITY=',A2,', WIND SPEED=',F5.2,' M/S,
     2 WIND DIRECTION=',F6.2,' DEG, MIXING HEIGHT=',F7.1,' M, AVERAGING
     3TIME=',I2,' HR.'//)
  906 FORMAT(1H1,'PEM-2 OUTPUT:  PREDICTED CONCENTRATIONS:  ',
     120A4/1X,I2,' SCENARIOS,',2X,'AVERAGING TIME=',I3,' HRS.'//)
  910 FORMAT(15X,'RECEPTOR',4X,'UNCALIBRATED CONCENTRATION',2X,'UNCALIB.
     1DEPOSITION FLUX',2X,'CALIBRATED CONCEN.POL-1:',7A4/14X,'COORDINATE
     2S',3X,'(MICROGRAMS/CUBIC METER)',3X,'(MICROGRAMS/SQ.M/HOUR)',3X,
     3'CALIBRATED CONCEN.POL-2:',7A4/1X,'COL ROW',5X,'X(KM)',3X,'Y(KM)',
     44X,'POL-1',11X,'POL-2',9X,'POL-1',8X,'POL-2',4X,'POL-1',8X,'POL-2'
     5/)
  970 FORMAT(2(2X,I2),2X,2(2X,F6.2),2X,F8.2,8X,F8.2,2(3X,F10.1),
     1 2(2X,E11.4))
  975 FORMAT(10F8.2)
      END
C
C
C
      SUBROUTINE ARRAY
C                        SUBROUTINE ARRAY  , PART OF PEM-2 (VERSION 84130).
C
C
C  SUBROUTINE ARRAY CREATES ARRAY MAPS OF THE CONCENTRATIONS AND
C     SURFACE DEPOSITION FLUXES IN THE RECEPTOR GRID AND
C     PRINTS THEM AT THE END OF EACH SCENARIO OR AVERAGING PERIOD.
C     UNCALIBRATED AND CALIBRATED CONCENTRATIONS OF EACH POLLUTANT
C     APPEAR ON SEPARATE MAPS OF UP TO FOUR SECTIONS (PAGES) EACH.
C     EACH SECTION (PAGE) ACCOMODATES VALUES AT 25X25 RECEPTORS.
C
C
C *** PEM MODIFICATIONS AND FORMATS BY M.M. STEVENS,
C     NOAA-ATDL, P.O. BOX E, OAK RIDGE, TN 37831
C     DECEMBER 1982
C *** PEM-2 MODIFICATIONS AND FORMATS BY K. SHANKAR RAO
C     JULY 1984
C
C
C
      COMMON/PEMCOM/CONC(50,50,2),SDF(50,50,2),TT(20),
     1 XP(300),YP(300),EP(300,2),HP(300),DP(300),VP(300),TP(300),
     2 XA(50),YA(50),EA(50,2),SIZE(50),
     3 WD(24),WS(24),TA(24),HMIX(24),DTDZI(24),
     4 AZ(6),BZ(6),CZ(6),P(6),SCLAB(6),DTDZ(2),SECTAN(16),
     5 XSWC,YSWC,GRID,LX,LY,A(2),B(2),POLNAM(3,2),CALNAM(7,2),
     6 ITA,IRD,IWR,IDSK,D80,D47,D8047,DIST,DELTA,HPRIME,
     7 ESH(2),PEAK,IBUOY,IRISE,IDWN,EFF,XS,UINV,WVEC,
     8 NAS,NPS,INDEX,IGRID,IAV,ISCEN,IWDOPT,IWD,ISC,IPS,
     9 NTOPT,NWDOPT,NWSOPT,NWPOPT,NSCEN,NLIST,NARRAY,NTAPE,NCSOPT,
     * NMAX,NSTDWN,NPRISE,NINPEN,INTER,NPRINT,NGPR,NBID
C
      COMMON/PARM1/NPOL,VD1,W1,VD2,W2
      DIMENSION X(50),CC(50),SSDF(50),DV(2),AVD(2)                      PMT28570
      INTEGER CC,SSDF                                                   PMT28580
C                                                                       PMT28590
      DV(1)=VD1                                                         PMT28600
      DV(2)=VD2                                                         PMT28610
      WOUT= WD(ISCEN)*180./3.1415927                                    PMT28620
      NLX=1                                                             PMT28630
      NLY=1                                                             PMT28640
      IF(LX.GT.25) NLX=2                                                PMT28650
      IF(LY.GT.25) NLY=2                                                PMT28660
      NSECT=NLX*NLY                                                     PMT28670
C                                                                       PMT28680
  100 ISECT=0                                                           PMT28690
      DO 700 JLX=1,NLX                                                  PMT28700
      MX2= JLX*25                                                       PMT28710
      IF(MX2.GT.LX) MX2=LX                                              PMT28720
      MX1=1                                                             PMT28730
      IF(JLX.EQ.2) MX1=26                                               PMT28740
      DO 125 I=MX1,MX2                                                  PMT28750
      XI=I                                                              PMT28760
125   X(I)= XSWC + (XI-0.5)*GRID                                        PMT28770
      DO 600 JLY=1,NLY                                                  PMT28780
      ISECT=ISECT+1                                                     PMT28790
      IF(JLY.EQ.1) GO TO 150                                            PMT28800
      MY1=26                                                            PMT28810
      MY2=LY                                                            PMT28820
      GO TO 175                                                         PMT28830
150   MY1=1                                                             PMT28840
      MY2=25                                                            PMT28850
      IF(LY.LT.25) MY2=LY                                               PMT28860
C                                                                       PMT28870
C                                                                       PMT28880
175   DO 500 N=1,NPOL                                                   PMT28890
      NREP=0                                                            PMT28900
  180 IF(NARRAY.EQ.3) GO TO 181                                         PMT28910
C     PRINT UNCALIBRATED ARRAYS OF CONCENTRATION AND DEPOSITION FLUX    PMT28920
C     (FOR NARRAY = 1 OR 2)                                             PMT28930
      IF(NTOPT.EQ.1) WRITE(IWR,900)ISECT,NSECT,ISCEN,TT                 PMT28940
      IF(NTOPT.GT.1) WRITE(IWR,901)ISECT,NSECT,TT                       PMT28950
      IF(NTOPT.EQ.1)WRITE(IWR,902)SCLAB(ISC),WS(ISCEN),WOUT,HMIX(ISCEN),PMT28960
     1             IAV,N,(POLNAM(L,N),L=1,3)                            PMT28970
      IF(NTOPT.GT.1) WRITE(IWR,903)ISCEN,IAV,N,(POLNAM(L,N),L=1,3)      PMT28980
C                                                                       PMT28990
      IF(NREP.EQ.0) GO TO 185                                           PMT29000
C    LOOP THROUGH SDF ARRAY TO FIND ANY VALUE GE 1000. IN THAT CASE,    PMT29010
C     SET FLAG TO SCALE SDF VALUES AS THEY ARE SET IN SSDF ARRAY        PMT29020
  181 IFLAG=0                                                           PMT29030
      DO 183 NX=1,LX                                                    PMT29040
      DO 183 NY=1,LY                                                    PMT29050
      IF(NARRAY.EQ.3) GO TO 182                                         PMT29060
      IF(SDF(NX,NY,N).GT.999.49) GO TO 184                              PMT29070
      GO TO 183                                                         PMT29080
  182 DUMMY=AVD(N)+B(N)*SDF(NX,NY,N)                                    PMT29090
      IF(DUMMY.GT.999.49) GO TO 184                                     PMT29100
  183 CONTINUE                                                          PMT29110
      IF(NARRAY.EQ.3) GO TO 320                                         PMT29120
      WRITE(IWR,905)                                                    PMT29130
      GO TO 190                                                         PMT29140
  184 IFLAG=1                                                           PMT29150
      IF(NARRAY.EQ.3) GO TO 320                                         PMT29160
      WRITE(IWR,910)                                                    PMT29170
      GO TO 190                                                         PMT29180
  185 WRITE(IWR,904)                                                    PMT29190
  190 WRITE(IWR,915) (X(I),I=MX1,MX2,2)                                 PMT29200
      DO 300 J=MY1,MY2                                                  PMT29210
      IY= MY2 + MY1 - J                                                 PMT29220
      Y=IY                                                              PMT29230
      Y= YSWC + (Y-0.5)*GRID                                            PMT29240
C                                                                       PMT29250
      IF(NREP.EQ.1) GO TO 240                                           PMT29260
      DO 230 I=MX1,MX2
230   CC(I)= CONC(I,IY,N) + 0.5
      WRITE(IWR,920)Y,(CC(I),I=MX1,MX2)
      GO TO 300
  240 DO 250 I=MX1,MX2
      IF(IFLAG.EQ.0) GO TO 245
      SSDF(I)=SDF(I,IY,N)*1.0E-03 + 0.5
      GO TO 250
  245 SSDF(I)= SDF(I,IY,N) + 0.5
  250 CONTINUE
      WRITE(IWR,920) Y,(SSDF(I),I=MX1,MX2)
 300  WRITE(IWR,925)Y
      WRITE(IWR,915)(X(I),I=MX1,MX2,2)
      IF(NARRAY.EQ.2) GO TO 450
C
C
C     PRINT CALIBRATED ARRAYS OF CONCENTRATION (FOR NARRAY = 1 OR 3)
C     AND DEPOSITION FLUX (FOR NARRAY = 3 ONLY)
  320 IF(NTOPT.EQ.1) WRITE(IWR,900)ISECT,NSECT,ISCEN,TT
      IF(NTOPT.GT.1) WRITE(IWR,901)ISECT,NSECT,TT
      IF(NTOPT.EQ.1)WRITE(IWR,902)SCLAB(ISC),WS(ISCEN),WOUT,HMIX(ISCEN),
     1              IAV,N,(POLNAM(L,N),L=1,3)
      IF(NTOPT.GT.1) WRITE(IWR,903)ISCEN,IAV,N,(POLNAM(L,N),L=1,3)
      IF(NREP.EQ.0) WRITE(IWR,906)(CALNAM(L,N),L=1,7),A(N),B(N)
      IF(NARRAY.EQ.1) GO TO 322
      IF(NREP.EQ.0) GO TO 322
      IF(IFLAG.EQ.0) WRITE(IWR,907)
      IF(IFLAG.EQ.1) WRITE(IWR,909)
C
  322 WRITE(IWR,915)(X(I),I=MX1,MX2,2)
      DO 400 J=MY1,MY2
      IY= MY2 + MY1 - J
      Y=IY
      Y= YSWC + (Y-0.5)*GRID
C
      IF(NREP.EQ.1) GO TO 340
      DO 330 I=MX1,MX2
 330  CC(I)= A(N) + B(N)*CONC(I,IY,N) + 0.5
      WRITE(IWR,920)Y,(CC(I),I=MX1,MX2)
      GO TO 400
  340 IF(NARRAY.EQ.1) GO TO 500
      DO 350 I=MX1,MX2
      SSDF(I)= AVD(N) + B(N) * SDF(I,IY,N)
      IF(IFLAG.EQ.1) SSDF(I)=SSDF(I)*1.0E-03
      SSDF(I)=SSDF(I)+0.5
  350 CONTINUE
      WRITE(IWR,920) Y,(SSDF(I),I=MX1,MX2)
 400  WRITE(IWR,925)Y
      WRITE(IWR,915)(X(I),I=MX1,MX2,2)
C
  450 IF(NREP.EQ.1) GO TO 500
C    IF NO SURF DEP FLUX WAS CALCULATED, SKIP PRINT
      IF(DV(N).LE.0.01) GO TO 500
      NREP=1
      AVD(N)=A(N)*DV(N)*36.
      GO TO 180
500   CONTINUE
600   CONTINUE
700   CONTINUE
C
      RETURN
C
900   FORMAT(1H1,'PEM-2 OUTPUT:  ','SECTION ',I1,' OF ',I1,', SCENARIO '
     1,I2,2X,20A4)
  901 FORMAT(1H1,'PEM-2 OUTPUT:  ','SECTION ',I1,' OF ',I1,3X,
     1 20A4)
902   FORMAT(' STABILITY=',A2,', WIND SPD=',F5.2,' M/S, WIND DIR=',F6.2,
     1 ' DEG, MIXING HT=',F7.1,' M, AVERAGING TIME=',I2,' HR.',6X,
     2 'POLLUTANT-',I1,': ',3A4)
  903 FORMAT(1X,I2,' SCENARIOS,',2X,'AVERAGING TIME=',I3,' HRS.',64X,
      1 'POLLUTANT-',I1,': ',3A4)
904   FORMAT(' UNCALIBRATED CONCENTRATION - MICROGRAMS PER CUBIC METER')
  905 FORMAT(' UNCALIBRATED SURFACE DEPOSITION FLUX - MICROGRAMS PER SQU
     1ARE METER PER HOUR')
906   FORMAT(' CALIBRATED CONCENTRATION - ',7A4,18X,'CALIBRATION COEFFIC
     1IENTS:  A =',F11.4,',   B =',F11.4)
  907 FORMAT(' CALIBRATED SURFACE DEPOSITION FLUX - MICROGRAMS PER SQUAR
     1E METER PER HOUR')
  909 FORMAT(' CALIBRATED SURFACE DEPOSITION FLUX - KILOGRAMS PER SQUARE
     1 KILOMETER PER HOUR')
  910 FORMAT(' UNCALIBRATED SURFACE DEPOSITION FLUX - KILOGRAMS PER SQUA
     1RE KILOMETER PER HOUR')
915   FORMAT(1H0,14X,13F8.2)
920   FORMAT(1H0,4X,F8.2,4X,25I4)
925   FORMAT(1H+,122X,F8.2)
      END
C
C
C
      SUBROUTINE WORST(I,J,CHI,N)
C                      SUBROUTINE WORST  , PART OF PEM-2 (VERSION 84130).
C
C
C  SUBROUTINE WORST DETERMINES THE FIVE POINT SOURCES CONTRIBUTING THE
C     MOST TO THE TOTAL CONCENTRATION AT EACH RECEPTOR. SOURCE
C     IDENTIFICATIONS AND CONTRIBUTIONS ARE STORED IN NWORST AND CWORST
C     RESPECTIVELY, FOR OUTPUT BY SUBROUTINE WOROUT.
C
C
C *** PEM MODIFICATIONS BY M.M. STEVENS,
C     NOAA-ATDL, P.O. BOX-E, OAK RIDGE, TENN 37831
C     DECEMBER 1982
C
C *** PEM-2 MODIFICATIONS BY K. S. RAO
C     DECEMBER 1984
C
C
      COMMON/PEMCOM/CONC(50,50,2),SDF(50,50,2),TT(20),
     1 XP(300),YP(300),EP(300,2),HP(300),DP(300),VP(300),TP(300),
     2 XA(50),YA(50),EA(50,2),SIZE(50),
     3 WD(24),WS(24),TA(24),HMIX(24),DTDZI(24),
     4 AZ(6),BZ(6),CZ(6),P(6),SCLAB(6),DTDZ(2),SECTAN(16),
     5 XSWC,YSWC,GRID,LX,LY,A(2),B(2),POLNAM(3,2),CALNAM(7,2),
     6 ITA,IRD,IWR,IDSK,D80,D47,D8047,DIST,DELTA,HPRIME,
     7 ESH(2),PEAK,IBUOY,IRISE,IDWN,EFF,XS,UINV,WVEC,
     8 NAS,NPS,INDEX,IGRID,IAV,ISCEN,IWDOPT,IWD,ISC,IPS,
     9 NTOPT,NWDOPT,NWSOPT,NWPOPT,NSCEN,NLIST,NARRAY,NTAPE,NCSOPT,
     * NMAX,NSTDWN,NPRISE,NINPEN,INTER,NPRINT,NGPR,NBID
C
      COMMON/CSWOR/NWORST(25,25,5,2),CWORST(25,25,5,2)
C
C
      IF(CHI.LE.CWORST(I,J,5,N)) RETURN
      IF(CHI.GT.CWORST(I,J,4,N)) GO TO 205
      CWORST(I,J,5,N)= CHI
      NWORST(I,J,5,N)= IPS
      RETURN
205   IF(CHI.GT.CWORST(I,J,3,N)) GO TO 210
      NW=1
      GO TO 225
210   IF(CHI.GT.CWORST(I,J,2,N)) GO TO 215
      NW=2
      GO TO 225
215   IF(CHI.GT.CWORST(I,J,1,N)) GO TO 220
      NW=3
      GO TO 225
220   NW=4
225   DO 250 IW=1,NW
      CWORST(I,J,6-IW,N)= CWORST(I,J,5-IW,N)
250   NWORST(I,J,6-IW,N)= NWORST(I,J,5-IW,N)
```

```
      CWORST(I,J,5-NW,N)= CHI                                           PMT30660
      NWORST(I,J,5-NW,N)= IPS                                           PMT30670
      RETURN                                                            PMT30680
      END                                                               PMT30690
C
C                                                                       PMT30700
C                                                                       PMT30710
      SUBROUTINE WOROUT                                                 PMT30720
C                   SUBROUTINE WOROUT , PART OF PEM-2 (VERSION 84130).  PMT30730
C                                                                       PMT30740
C                                                                       PMT30750
C   SUBROUTINE WOROUT PRINTS A CULPABILITY LIST OF THE FIVE POINT SOURCESPMT30760
C     WHICH CONTRIBUTE MOST TO THE TOTAL CONCENTRATION OF EACH POLLUTANT.PMT30770
C     THIS ROUTINE LISTS THE FIVE POINT SOURCES AND THEIR PERCENTAGE    PMT30780
C     CONTRIBUTIONS TO THE TOTAL CONCENTRATION AND SURFACE DEPOSITION   PMT30790
C     FLUX AT EACH RECEPTOR.                                            PMT30800
C     TO REDUCE OUTPUT, ONLY RECEPTORS WITH THE HIGHEST CONTRIBUTIONS   PMT30810
C     EXCEEDING 1 MICROGRAM PER CUBIC METER ARE PRINTED.                PMT30820
C     USING DATA COMPILED BY SUBROUTINE WORST, THIS INFORMATION IS      PMT30830
C     PRINTED AT THE END OF EACH SCENARIO OR SUB-SCENARIO FOR NTOPT=1.  PMT30840
C                                                                       PMT30850
C                                                                       PMT30860
C *** PEM MODIFICATIONS AND FORMATS BY M.M. STEVENS,                    PMT30870
C     NOAA-ATDL, P.O. BOX E, OAK RIDGE, TN 37831                        PMT30880
C     DECEMBER 1982                                                     PMT30890
C *** PEM-2 MODIFICATIONS BY K. S. RAO                                  PMT30900
C     DECEMBER 1984                                                     PMT30910
C                                                                       PMT30920
C                                                                       PMT30930
      COMMON/PEMCOM/CONC(50,50,2),SDF(50,50,2),TT(20),                  PMT30940
     1 XP(300),YP(300),EP(300,2),HP(300),DP(300),VP(300),TP(300),       PMT30950
     2 XA(50),YA(50),EA(50,2),SIZE(50),                                 PMT30960
     3 WD(24),WS(24),TA(24),HMIX(24),DTDZI(24),                         PMT30970
     4 AZ(6),BZ(6),CZ(6),P(6),SCLAB(6),DTDZ(2),SECTAN(16),              PMT30980
     5 XSWC,YSWC,GRID,LX,LY,A(2),B(2),POLNAM(3,2),CALNAM(7,2),          PMT30990
     6 ITA,IRD,IWR,IDSK,D80,D47,D8047,DIST,DELTA,HPRIME,                PMT31000
     7 ESH(2),PEAK,IBUOY,IRISE,IDWN,EFF,XS,UINV,WVEC,                   PMT31010
     8 NAS,NPS,INDEX,IGRID,IAV,ISCEN,IWDOPT,IWD,ISC,IPS,                PMT31020
     9 NTOPT,NWDOPT,NWSOPT,NWPOPT,NSCEN,NLIST,NARRAY,NTAPE,NCSOPT,      PMT31030
     * NMAX,NSTDWN,NPRISE,NINPEN,INTER,NPRINT,NGPR,NBID                 PMT31040
C                                                                       PMT31050
      COMMON/CSWOR/NWORST(25,25,5,2),CWORST(25,25,5,2)                  PMT31060
      COMMON/PARM1/NPOL,VD1,W1,VD2,W2                                   PMT31070
C                                                                       PMT31080
C                                                                       PMT31090
C     START DO-LOOP ON POLLUTANT SPECIES                                PMT31100
      DO 400 K=1,NPOL                                                   PMT31110
      WRITE(IWR,905) TT,ISCEN                                           PMT31120
      IF(NWDOPT.LE.1) GO TO 200                                         PMT31130
      WOUT=WD(ISCEN)*180./3.1415927                                     PMT31140
      WRITE(IWR,910) WOUT                                               PMT31150
C                                                                       PMT31160
  200 WRITE(IWR,920) K,(POLNAM(M,K),M=1,3)                              PMT31170
      WRITE(IWR,915)                                                    PMT31180
C                                                                       PMT31190
C     START DO-LOOP ON RECEPTOR GRID COLUMNS                            PMT31200
      DO 350 I=1,LX                                                     PMT31210
      XI=I                                                              PMT31220
      X= XSWC + (XI-0.5)*GRID                                           PMT31230
C                                                                       PMT31240
C     START DO-LOOP ON RECEPTOR GRID ROWS                               PMT31250
      DO 300 J=1,LY                                                     PMT31260
C                                                                       PMT31270
C     SUPPRESS PRINT IF THE HIGHEST CONCENTRATION IS INSIGNIFICANT      PMT31280
      IF(CWORST(I,J,1,K).LT.1.0) GO TO 300                              PMT31290
C                                                                       PMT31300
C     START DO-LOOP TO CONVERT FIVE HIGHEST CONTRIBUTIONS TO            PMT31310
C     PERCENTAGES OF TOTAL CONCENTRATION AT THE RECEPTOR                PMT31320
      DO 250 L=1,5                                                      PMT31330
      CWORST(I,J,L,K)=CWORST(I,J,L,K)*100./CONC(I,J,K)                  PMT31340
  250 CONTINUE                                                          PMT31350
C     END LOOP ON FIVE HIGHEST CONTRIBUTIONS                            PMT31360
C                                                                       PMT31370
      YJ=J                                                              PMT31380
      Y= YSWC + (YJ-0.5)*GRID                                           PMT31390
      WRITE(IWR,925)I,J,X,Y,NWORST(I,J,1,K),CWORST(I,J,1,K),NWORST(I,J,2PMT31400
     1,K),CWORST(I,J,2,K),NWORST(I,J,3,K),CWORST(I,J,3,K),NWORST(I,J,4,KPMT31410
     2),CWORST(I,J,4,K),NWORST(I,J,5,K),CWORST(I,J,5,K),CONC(I,J,K),SDF(PMT31420
     3I,J,K)                                                            PMT31430
C                                                                       PMT31440
  300 CONTINUE                                                          PMT31450
C     END LOOP ON GRID ROWS                                             PMT31460
  350 CONTINUE                                                          PMT31470
C     END LOOP ON GRID COLUMNS                                          PMT31480
  400 CONTINUE                                                          PMT31490
C     END LOOP ON SPECIES                                               PMT31500
C                                                                       PMT31510
      RETURN                                                            PMT31520
C                                                                       PMT31530
  905 FORMAT(1H1,37X,'POLLUTION EPISODIC MODEL (PEM-2)'///4X,'OUTPUT:  'PMT31540
     1,20A4//4X,'LIST OF THE FIVE POINT SOURCES WHICH PRODUCE THE HIGHESPMT31550
     2T VALUES OF CONCENTRATION AND SURFACE DEPOSITION FLUX AT EACH RECEPMT31560
     3PTOR'//5X,'SCENARIO',14X,'  -  CONCENTRATION IN MICROGRAMS PER ', PMT31570
     4'CUBIC METER'/6X,'NUMBER: ',I2,16X,'SURFACE DEPOSITION FLUX IN MICPMT31580
     5ROGRAMS PER SQUARE METER PER HOUR'/)                              PMT31590
  910 FORMAT(6X,'WIND DIRECTION = ',F5.1,' DEG'/)                       PMT31600
  915 FORMAT(45X,'POINT SOURCE SEQUENCE NUMBER AND PERCENT'/            PMT31610
     115X,'COORDINATES',15X,'OF TOTAL CONCENTRATION AND SURFACE DEPOSITIPMT31620
     2ON FLUX',14X,'TOTAL',8X,'TOTAL SURFACE'/                          PMT31630
     3' COL ROW',4X,'X (KM)',4X,'Y (KM)',9X,'HIGHEST',6X,'SECOND',8X,   PMT31640
     4'THIRD',7X,'FOURTH',8X,'FIFTH',6X,'CONCENTRATION',3X,'DEPOSITION FPMT31650
     5LUX'/)                                                            PMT31660
  920 FORMAT(45X,'POLLUTANT-',I1,' :',3A4)                              PMT31670
  925 FORMAT(2(2X,I2),3X,F8.2,2X,F8.2,3X,5(3X,I3,F7.2),6X,F8.2,9X,F8.2) PMT31680
C                                                                       PMT31690
      END                                                               PMT31700
C
C                                                                       PMT31710
C                                                                       PMT31720
      SUBROUTINE SCENMX                                                 PMT31730
C                    SUBROUTINE SCENMX , PART OF PEM-2 (VERSION 84130). PMT31740
C                                                                       PMT31750
C                                                                       PMT31760
C  SUBROUTINE SCENMX LOCATES AND STORES THE COORDINATES, CONCENTRATION, PMT31770
C  AND SURFACE DEPOSITION FLUX AT THE RECEPTOR GRID POINTS RECORDING    PMT31780
C  THE HIGHEST CONCENTRATION AND SURFACE DEPOSITION FLUX OF EACH        PMT31790
C  POLLUTANT IN EACH SCENARIO (IF NTOPT=1) OR AVERAGING-PERIOD (IF     PMT31800
C  NTOPT>1).                                                           PMT31810
C                                                                       PMT31820
C  THE STORED VALUES ARE PRINTED BY SUBROUTINE MAXOUT AT THE END OF RUN.PMT31830
C                                                                       PMT31840
C                                                                       PMT31850
C *** PEM MODIFICATIONS BY M.M. STEVENS,                                PMT31860
C     NOAA-ATDL, P.O.BOX - E, OAK RIDGE, TN 37831                       PMT31870
C     DECEMBER 1982                                                     PMT31880
C                                                                       PMT31890
C                                                                       PMT31900
      COMMON/PEMCOM/CONC(50,50,2),SDF(50,50,2),TT(20),                  PMT31910
     1 XP(300),YP(300),EP(300,2),HP(300),DP(300),VP(300),TP(300),       PMT31920
     2 XA(50),YA(50),EA(50,2),SIZE(50),                                 PMT31930
     3 WD(24),WS(24),TA(24),HMIX(24),DTDZI(24),                         PMT31940
     4 AZ(6),BZ(6),CZ(6),P(6),SCLAB(6),DTDZ(2),SECTAN(16),              PMT31950
     5 XSWC,YSWC,GRID,LX,LY,A(2),B(2),POLNAM(3,2),CALNAM(7,2),          PMT31960
     6 ITA,IRD,IWR,IDSK,D80,D47,D8047,DIST,DELTA,HPRIME,                PMT31970
     7 ESH(2),PEAK,IBUOY,IRISE,IDWN,EFF,XS,UINV,WVEC,                   PMT31980
     8 NAS,NPS,INDEX,IGRID,IAV,ISCEN,IWDOPT,IWD,ISC,IPS,                PMT31990
     9 NTOPT,NWDOPT,NWSOPT,NWPOPT,NSCEN,NLIST,NARRAY,NTAPE,NCSOPT,      PMT32000
     * NMAX,NSTDWN,NPRISE,NINPEN,INTER,NPRINT,NGPR,NBID                 PMT32010
C                                                                       PMT32020
      COMMON/MAX/XMX(24,4,2),YMX(24,4,2),ZMX(24,4,2),SMX(24,4,2)        PMT32030
      COMMON/PARM1/NPOL,VD1,W1,VD2,W2
C
C
      IF(NTOPT.EQ.1) GO TO 120
      I= 1
      GO TO 130
120   I= ISCEN
130   IF(NWDOPT.LE.1) GO TO 140
      J= IWDOPT
      GO TO 150
140   J= 1
150   DO 400 K=1,NPOL
      Z= 0.
      DO 350 NX=1,LX
      DO 350 NY=1,LY
      IF(CONC(NX,NY,K).LT.Z) GO TO 350
      Z= CONC(NX,NY,K)
      ZS=SDF(NX,NY,K)
      ZX=NX
      ZY=NY
350   CONTINUE
      ZMX(I,J,K)= Z
      SMX(I,J,K)=ZS
      XMX(I,J,K)= XSWC + (ZX - 0.5)*GRID
      YMX(I,J,K)= YSWC + (ZY - 0.5)*GRID
400   CONTINUE
      RETURN
      END
C
C
C
      SUBROUTINE MAXOUT
C                   SUBROUTINE MAXOUT , PART OF PEM-2 (VERSION 84130).
C
C
C  SUBROUTINE MAXOUT PRINTS THE COORDINATES, CONCENTRATION, AND
C  SURFACE DEPOSITION FLUX AT THE RECEPTOR GRID POINTS RECORDING
C  THE HIGHEST CONCENTRATION OF EACH POLLUTANT IN EACH SCENARIO OR
C  AVERAGING PERIOD. THESE VALUES WERE SELECTED AND STORED BY SUB-
C  ROUTINE SCENMX.
C
C
C
C *** PEM MODIFICATIONS AND FORMATS BY M.M. STEVENS,
C     NOAA-ATDL, P.O.BOX E, OAK RIDGE, TN 37831
C     DECEMBER 1982
C *** PEM-2 MODIFICATIONS BY K. S. RAO
C     DECEMBER 1984
C
C
      COMMON/PEMCOM/CONC(50,50,2),SDF(50,50,2),TT(20),
     1 XP(300),YP(300),EP(300,2),HP(300),DP(300),VP(300),TP(300),
     2 XA(50),YA(50),EA(50,2),SIZE(50),
     3 WD(24),WS(24),TA(24),HMIX(24),DTDZI(24),
     4 AZ(6),BZ(6),CZ(6),P(6),SCLAB(6),DTDZ(2),SECTAN(16),
     5 XSWC,YSWC,GRID,LX,LY,A(2),B(2),POLNAM(3,2),CALNAM(7,2),
     6 ITA,IRD,IWR,IDSK,D80,D47,D8047,DIST,DELTA,HPRIME,
     7 ESH(2),PEAK,IBUOY,IRISE,IDWN,EFF,XS,UINV,WVEC,
     8 NAS,NPS,INDEX,IGRID,IAV,ISCEN,IWDOPT,IWD,ISC,IPS,
     9 NTOPT,NWDOPT,NWSOPT,NWPOPT,NSCEN,NLIST,NARRAY,NTAPE,NCSOPT,
     * NMAX,NSTDWN,NPRISE,NINPEN,INTER,NPRINT,NGPR,NBID
C
      COMMON/MAX/XMX(24,4,2),YMX(24,4,2),ZMX(24,4,2),SMX(24,4,2)
      COMMON/PARM1/NPOL,VD1,W1,VD2,W2
      DIMENSION ZC(2),ZS(2),AVD(2)
C
C   CHECK WHETHER SURF DEP FLUX WAS CALCULATED AND SET FLAG
      NREP=0
      IF(VD1.GE.0.01 .OR. VD2.GE.0.01) GO TO 100
      GO TO 110
```

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  100 NREP=1                                                            PMT32730
      AVD(1)=A(1)*VD1*36.                                               PMT32740
      AVD(2)=A(2)*VD2*36.                                               PMT32750
C                                                                       PMT32760
  110 IF(NWDOPT.GT.1) GO TO 300                                         PMT32770
C                                                                       PMT32780
      J=1                                                               PMT32790
      N=1                                                               PMT32800
      IF(NTOPT.EQ.1) N=NSCEN                                            PMT32810
C    PRINT HIGHEST CONCENTRATIONS                                       PMT32820
      WRITE(IWR,900) TT                                                 PMT32830
      WRITE(IWR,902) (CALNAM(L,1),L=1,7)                                PMT32840
      IF(NPOL.EQ.2) WRITE(IWR,903) (CALNAM(L,2),L=1,7)                  PMT32850
      WRITE(IWR,910) (POLNAM(L,1),L=1,3)                                PMT32860
      IF(NPOL.EQ.2) WRITE(IWR,911) (POLNAM(L,2),L=1,3)                  PMT32870
      WRITE(IWR,912)                                                    PMT32880
      WRITE(IWR,915)                                                    PMT32890
      DO 200 I=1,N                                                      PMT32900
      DO 120 K=1,NPOL                                                   PMT32910
  120 ZC(K)= A(K) + B(K)*ZMX(I,1,K)                                     PMT32920
      WRITE(IWR,920)                                                    PMT32930
      WRITE(IWR,923) I,(XMX(I,1,K),YMX(I,1,K),ZMX(I,1,K),ZC(K),         PMT32940
     1 K=1,NPOL)                                                        PMT32950
  200 CONTINUE                                                          PMT32960
C                                                                       PMT32970
C    PRINT SURFACE DEPOSITION FLUX VALUES                               PMT32980
C    IF NO SURF DEP FLUX WAS CALCULATED, SKIP PRINT                     PMT32990
      IF(NREP.EQ.0) RETURN                                              PMT33000
      WRITE(IWR,900) TT                                                 PMT33010
      WRITE(IWR,932) (CALNAM(L,1),L=1,7)                                PMT33020
      IF(NPOL.EQ.2) WRITE(IWR,933) (CALNAM(L,2),L=1,7)                  PMT33030
      WRITE(IWR,910) (POLNAM(L,1),L=1,3)                                PMT33040
      IF(NPOL.EQ.2) WRITE(IWR,911) (POLNAM(L,2),L=1,3)                  PMT33050
      WRITE(IWR,942)                                                    PMT33060
      WRITE(IWR,915)                                                    PMT33070
      DO 250 I=1,N                                                      PMT33080
      DO 220 K=1,NPOL                                                   PMT33090
  220 ZS(K)= AVD(K) + B(K)*SMX(I,1,K)                                   PMT33100
      WRITE(IWR,920)                                                    PMT33110
      WRITE(IWR,923) I,(XMX(I,1,K),YMX(I,1,K),SMX(I,1,K),ZS(K),         PMT33120
     1 K=1,NPOL)                                                        PMT33130
  250 CONTINUE                                                          PMT33140
C                                                                       PMT33150
      RETURN                                                            PMT33160
C                                                                       PMT33170
C    PRINT FOR CASE OF NWDOPT>1  -  SUB-SCENARIOS                       PMT33180
  300 N=NSCEN                                                           PMT33190
C    PRINT HIGHEST CONCENTRATIONS                                       PMT33200
      DO 500 I=1,N                                                      PMT33210
      IF(((I-1)/8)*8.NE.I-1) GO TO 310                                  PMT33220
      WRITE(IWR,900) TT                                                 PMT33230
      WRITE(IWR,902) (CALNAM(L,1),L=1,7)                                PMT33240
      IF(NPOL.EQ.2) WRITE(IWR,903) (CALNAM(L,2),L=1,7)                  PMT33250
      WRITE(IWR,910) (POLNAM(L,1),L=1,3)                                PMT33260
      IF(NPOL.EQ.2) WRITE(IWR,911) (POLNAM(L,2),L=1,3)                  PMT33270
      WRITE(IWR,912)                                                    PMT33280
      WRITE(IWR,915)                                                    PMT33290
  310 WRITE(IWR,920)                                                    PMT33300
      DO 400 J=1,4                                                      PMT33310
      DO 320 K=1,NPOL                                                   PMT33320
  320 ZC(K)= A(K) + B(K)*ZMX(I,J,K)                                     PMT33330
      WRITE(IWR,925) I,J,(XMX(I,J,K),YMX(I,J,K),ZMX(I,J,K),ZC(K),       PMT33340
     1 K=1,NPOL)                                                        PMT33350
  400 CONTINUE                                                          PMT33360
  500 CONTINUE                                                          PMT33370
C                                                                       PMT33380
C    PRINT SURFACE DEPOSITION FLUX VALUES                               PMT33390
C    IF NO SURF DEP FLUX WAS CALCULATED, SKIP PRINT                     PMT33400
      IF(NREP.EQ.0) RETURN                                              PMT33410
      DO 600 I=1,N                                                      PMT33420
      IF(((I-1)/8)*8.NE.I-1) GO TO 510
      WRITE(IWR,900) TT
      WRITE(IWR,932) (CALNAM(L,1),L=1,7)
      IF(NPOL.EQ.2) WRITE(IWR,933) (CALNAM(L,2),L=1,7)
      WRITE(IWR,910) (POLNAM(L,1),L=1,3)
      IF(NPOL.EQ.2) WRITE(IWR,911) (POLNAM(L,2),L=1,3)
      WRITE(IWR,942)
      WRITE(IWR,915)
  510 WRITE(IWR,920)
      DO 550 J=1,4
      DO 520 K=1,NPOL
  520 ZS(K)= AVD(K) + B(K)*SMX(I,J,K)
      WRITE(IWR,925) I,J,(XMX(I,J,K),YMX(I,J,K),SMX(I,J,K),ZS(K),
     1 K=1,NPOL)
  550 CONTINUE
  600 CONTINUE
C
  700 RETURN
C
  900 FORMAT(1H1,37X,'POLLUTION EPISODIC MODEL (PEM-2)'///4X,'OUTPUT:  '
     1,20A4//)
  902 FORMAT(4X,'HIGHEST PREDICTED CONCENTRATION OF EACH POLLUTANT FOR E
     1ACH SCENARIO OR AVERAGING PERIOD'//4X,'UNCALIBRATED CONCENTRATION
     2IN MICROGRAMS PER CUBIC METER  -  CALIBRATION, POLLUTANT-1: ',7A4)
  903 FORMAT(65X,'CALIBRATION, POLLUTANT-2: ',7A4)
  910 FORMAT(//40X,'POLLUTANT-1: ',3A4)
  911 FORMAT(1H+,93X,'POLLUTANT-2: ',3A4)
  912 FORMAT(/' SCENARIO  WIND DIRECTION',7X,'COORDINATES',14X,
     1'CONCENTRATION',16X,'COORDINATES',14X,'CONCENTRATION')
  915 FORMAT(2X,'NUMBER',4X,'SUB-SCENARIO',6X,'X(KM)',5X,'Y(KM)',6X,
     1'UNCALIBRATED',4X,'CALIBRATED',7X,'X(KM)',5X,'Y(KM)',6X,
     2'UNCALIBRATED',4X,'CALIBRATED'/)
  920 FORMAT(1X)
  923 FORMAT(4X,I2,21X,F9.2,1X,F9.2,5X,F11.4,4X,F11.4,4X,F9.2,1X,
     1F9.2,5X,F11.4,4X,F11.4)
  925 FORMAT(4X,I2,11X,I2,8X,F9.2,1X,F9.2,5X,F11.4,4X,F11.4,4X,F9.2,1X,
     1F9.2,5X,F11.4,4X,F11.4)
  932 FORMAT(4X,'HIGHEST PREDICTED SURFACE DEPOSITION FLUX OF EACH POLLU
     1TANT FOR EACH SCENARIO OR AVERAGING PERIOD'//4X,'UNCALIBRATED VALU
     2ES IN MICROGRAMS PER SQUARE METER PER HOUR  -  CALIBRATION, POLLUT
     3ANT-1: ',7A4)
  933 FORMAT(68X,'CALIBRATION, POLLUTANT-2: ',7A4)
  942 FORMAT(/' SCENARIO  WIND DIRECTION',7X,'COORDINATES',9X,
     1'SURFACE DEPOSITION FLUX',11X,'COORDINATES',9X,'SURFACE DEPOSITION
     2 FLUX')
      END
C
C
C
      SUBROUTINE RISE
C                    SUBROUTINE RISE   , PART OF PEM-2 (VERSION 84130).
C
C
C  SUBROUTINE RISE CALCULATES PLUME RISE VIA THE STANDARD EQUATIONS
C    OF BRIGGS (1971,1969) IF NPRISE=0. IF NPRISE=1 OPTION IS SELECTED,
C    THE NEW PLUME RISE EQUATIONS OF BRIGGS (1984,1975) ARE USED FOR THE
C    BUOYANCY-DOMINATED PEAK PLUME RISE IN UNSTABLE/NEUTRAL CONDITIONS.
C    IF IRISE=1, THE DISTANCE-DEPENDENT EFFECTIVE SOURCE HEIGHT (ESH(1))
C    IS RETURNED. IF IRISE=2, MAXIMUM EFFECTIVE SOURCE HEIGHT (ESH(2) IS
C    RETURNED. RISE IS CALLED ONLY ONCE PER SOURCE PER SCENARIO WITH
C    IRISE=2. IT IS CALLED WITH IRISE=1 WHENEVER THE DOWNWIND DISTANCE
C    (DIST) IS LESS THAN THE DISTANCE TO MAXIMUM PLUME RISE (PEAK).
C    SUBROUTINE RISE IS CALLED IN THE MAIN PROGRAM, AND IN SUBROUTINES
C    QZCAL AND AUTGRD.
C
C
C     PEM-2 MODIFICATIONS: APRIL 1984
C     K.SHANKAR RAO
C     NOAA-ATDL, P.O. BOX-E
C     OAK RIDGE, TENN 37831
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C
C
      COMMON/PEMCOM/CONC(50,50,2),SDF(50,50,2),TT(20),
     1 XP(300),YP(300),EP(300,2),HP(300),DP(300),VP(300),TP(300),
     2 XA(50),YA(50),EA(50,2),SIZE(50),
     3 WD(24),WS(24),TA(24),HMIX(24),DTDZI(24),
     4 AZ(6),BZ(6),CZ(6),P(6),SCLAB(6),DTDZ(2),SECTAN(16),
     5 XSWC,YSWC,GRID,LX,LY,A(2),B(2),POLNAM(3,2),CALNAM(7,2),
     6 ITA,IRD,IWR,IDSK,D80,D47,D8047,DIST,DELTA,HPRIME,
     7 ESH(2),PEAK,IBUOY,IRISE,IDWN,EFF,XS,UINV,WVEC,
     8 NAS,NPS,INDEX,IGRID,IAV,ISCEN,IWDOPT,IWD,ISC,IPS,
     9 NTOPT,NWDOPT,NWSOPT,NWPOPT,NSCEN,NLIST,NARRAY,NTAPE,NCSOPT,
     * NMAX,NSTDWN,NPRISE,NINPEN,INTER,NPRINT,NGPR,NBID
C
      IDWN=1
      IF(IRISE.EQ.1) GO TO 200
C
C     IRISE=2: DETERMINE WHETHER THE PLUME IS DOMINATED BY MOMENTUM OR
C     BUOYANCY, AND CALCULATE OPTIONAL STACK-TIP DOWNWASH CORRECTION,
C     MAXIMUM EFFECTIVE SOURCE HEIGHT, AND VALUES OF CONSTANT FACTORS IN
C     RELATED DISTANCE-DEPENDENT PLUME RISE EQUATIONS.
      HPRIME=HP(IPS)
      IF(NSTDWN.EQ.1) GO TO 10
C
C     NSTDWN=0; DOWNWASH CORRECTION.
      RATV=VP(IPS)*UINV
      IF(RATV.GE.1.5) GO TO 10
      DWNWSH=2.0*(1.5-RATV)*DP(IPS)
      IDWN=3
      IF(DWNWSH.GE.HP(IPS)) DWNWSH=HP(IPS)
      HPRIME=HP(IPS)-DWNWSH
C
C     DETERMINE IF PLUME IS MOMENTUM-DOMINATED (IBUOY=0)
C                        OR BUOYANCY-DOMINATED (IBUOY=1),
C     USING THE BUOYANCY - MOMENTUM CROSSOVER TECHNIQUES.
   10 IBUOY=1
      CVD3=3.0*VP(IPS)*DP(IPS)
      DELHUM=CVD3*UINV
      IF(ISC.LT.5) GO TO 20
C     STABILITY CLASSES E AND F.
      IF(ISC.EQ.6) GO TO 15
      BRIGC=115.28
      DIF=ABS(DTDZ(1)-0.02)
      GO TO 16
   15 BRIGC= 87.14
      DIF=ABS(DTDZ(2)-0.035)
   16 IF(DIF.GT.0.001) BRIGC=16.30/SQRT(DTDZ(ISC-4))
      IF(VP(IPS).GT.BRIGC*(TP(IPS)-TA(ISCEN))/SQRT(TA(ISCEN))) IBUOY=0
      IF(IBUOY.EQ.0) GO TO 90
      GO TO 60
   20 IF(NPRISE.EQ.1) GO TO 50
C
C     NPRISE=0: STANDARD (DEFAULT) PLUME RISE EQS. STABILITY CLASSES A-D
      IF(EFF.GE.55.) GO TO 30
      AF=21.425
      BF=0.75
      GO TO 40
   30 AF=38.710
      BF=0.6
   40 IF(CVD3.GT.AF*EFF**BF) IBUOY=0
      IF(IBUOY.EQ.0) GO TO 80
      IF(EFF.LT.55.) XS=49.*(EFF**0.625)
      IF(EFF.GE.55.) XS=119.*(EFF**0.4)
      GO TO 60
C
C     NPRISE=1: NEW (OPTIONAL) PLUME RISE EQS. STABILITY CLASSES A-D.
   50 DELH1=30.*(EFF*UINV)**0.6
      FOU3=EFF*(UINV**3)
      TERMH2=HPRIME+200.*FOU3
      DELH2=24.*(FOU3**0.6)*(TERMH2**0.4)
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C                                                                       PMT34120
C                                                                       PMT34130
      COMMON/PEMCOM/CONC(50,50,2),SDF(50,50,2),TT(20),                  PMT34140
     1 XP(300),YP(300),EP(300,2),HP(300),DP(300),VP(300),TP(300),       PMT34150
     2 XA(50),YA(50),EA(50,2),SIZE(50),                                 PMT34160
     3 WD(24),WS(24),TA(24),HMIX(24),DTDZI(24),                         PMT34170
     4 AZ(6),BZ(6),CZ(6),P(6),SCLAB(6),DTDZ(2),SECTAN(16),              PMT34180
     5 XSWC,YSWC,GRID,LX,LY,A(2),B(2),POLNAM(3,2),CALNAM(7,2),          PMT34190
     6 ITA,IRD,IWR,IDSK,D80,D47,D8047,DIST,DELTA,HPRIME,                PMT34200
     7 ESH(2),PEAK,IBUOY,IRISE,IDWN,EFF,XS,UINV,WVEC,                   PMT34210
     8 NAS,NPS,INDEX,IGRID,IAV,ISCEN,IWDOPT,IWD,ISC,IPS,                PMT34220
     9 NTOPT,NWDOPT,NWSOPT,NWPOPT,NSCEN,NLIST,NARRAY,NTAPE,NCSOPT,      PMT34230
     * NMAX,NSTDWN,NPRISE,NINPEN,INTER,NPRINT,NGPR,NBID                 PMT34240
C                                                                       PMT34250
      IDWN=1                                                            PMT34260
      IF(IRISE.EQ.1) GO TO 200                                          PMT34270
C                                                                       PMT34280
C     IRISE=2: DETERMINE WHETHER THE PLUME IS DOMINATED BY MOMENTUM OR  PMT34290
C     BUOYANCY, AND CALCULATE OPTIONAL STACK-TIP DOWNWASH CORRECTION,   PMT34300
C     MAXIMUM EFFECTIVE SOURCE HEIGHT, AND VALUES OF CONSTANT FACTORS INPMT34310
C     RELATED DISTANCE-DEPENDENT PLUME RISE EQUATIONS.                  PMT34320
      HPRIME=HP(IPS)                                                    PMT34330
      IF(NSTDWN.EQ.1) GO TO 10                                          PMT34340
C                                                                       PMT34350
C     NSTDWN=0; DOWNWASH CORRECTION.                                    PMT34360
      RATV=VP(IPS)*UINV                                                 PMT34370
      IF(RATV.GE.1.5) GO TO 10                                          PMT34380
      DWNWSH=2.0*(1.5-RATV)*DP(IPS)                                     PMT34390
      IDWN=3                                                            PMT34400
      IF(DWNWSH.GE.HP(IPS)) DWNWSH=HP(IPS)                              PMT34410
      HPRIME=HP(IPS)-DWNWSH                                             PMT34420
C                                                                       PMT34430
C     DETERMINE IF PLUME IS MOMENTUM-DOMINATED (IBUOY=0)                PMT34440
C                           OR BUOYANCY-DOMINATED (IBUOY=1),            PMT34450
C     USING THE BUOYANCY - MOMENTUM CROSSOVER TECHNIQUES.               PMT34460
   10 IBUOY=1                                                           PMT34470
      CVD3=3.0*VP(IPS)*DP(IPS)                                          PMT34480
      DELHUM=CVD3*UINV                                                  PMT34490
      IF(ISC.LT.5) GO TO 20                                             PMT34500
C     STABILITY CLASSES E AND F.                                        PMT34510
      IF(ISC.EQ.6) GO TO 15                                             PMT34520
      BRIGC=115.28                                                      PMT34530
      DIF=ABS(DTDZ(1)-0.02)                                             PMT34540
      GO TO 16                                                          PMT34550
   15 BRIGC= 87.14                                                      PMT34560
      DIF=ABS(DTDZ(2)-0.035)                                            PMT34570
   16 IF(DIF.GT.0.001) BRIGC=16.30/SQRT(DTDZ(ISC-4))                    PMT34580
      IF(VP(IPS).GT.BRIGC*(TP(IPS)-TA(ISCEN))/SQRT(TA(ISCEN))) IBUOY=0  PMT34590
      IF(IBUOY.EQ.0) GO TO 90                                           PMT34600
      GO TO 60                                                          PMT34610
   20 IF(NPRISE.EQ.1) GO TO 50                                          PMT34620
C                                                                       PMT34630
C     NPRISE=0: STANDARD (DEFAULT) PLUME RISE EQS. STABILITY CLASSES A-DPMT34640
      IF(EFF.GE.55.) GO TO 30                                           PMT34650
      AF=21.425                                                         PMT34660
      BF=0.75                                                           PMT34670
      GO TO 40                                                          PMT34680
   30 AF=38.710                                                         PMT34690
      BF=0.6                                                            PMT34700
   40 IF(CVD3.GT.AF*EFF**BF) IBUOY=0                                    PMT34710
      IF(IBUOY.EQ.0) GO TO 80                                           PMT34720
      IF(EFF.LT.55.) XS=49.*(EFF**0.625)                                PMT34730
      IF(EFF.GE.55.) XS=119.*(EFF**0.4)                                 PMT34740
      GO TO 60                                                          PMT34750
C                                                                       PMT34760
C     NPRISE=1: NEW (OPTIONAL) PLUME RISE EQS. STABILITY CLASSES A-D.   PMT34770
   50 DELH1=30.*(EFF*UINV)**0.6                                         PMT34780
      FOU3=EFF*(UINV**3)                                                PMT34790
      TERMH2=HPRIME+200.*FOU3                                           PMT34800
      DELH2=24.*(FOU3**0.6)*(TERMH2**0.4)                               PMT34810
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C     SELECT THE LOWER VALUE GIVEN BY THE TWO BUOYANCY RISE EQUATIONS.  PMT34820
      DELTAH=DELH1                                                      PMT34830
      IF(DELH2.LT.DELH1) DELTAH=DELH2                                   PMT34840
C     SELECT THE HIGHER VALUE GIVEN BY THE MOMENTUM RISE AND DELTAH.    PMT34850
      IF(DELHUM.GT.DELTAH) IBUOY=0                                      PMT34860
      IF(IBUOY.EQ.0) GO TO 80                                           PMT34870
      IF(DELH2.GE.DELH1) XS=81.19*(EFF**0.4)/(UINV**0.6)                PMT34880
      IF(DELH2.LT.DELH1) XS=58.09*(FOU3**0.4)*(TERMH2**0.6)             PMT34890
C                                                                       PMT34900
   60 CTB= 1.6*UINV*EFF**0.333333                                       PMT34910
      IF(ISC.GE.5) GO TO 70                                             PMT34920
      IF(NPRISE.EQ.1) GO TO 100                                         PMT34930
C                                                                       PMT34940
C  PEAK PLUME RISE: BUOYANCY-DOMINATED PLUME, UNSTABLE AIR (A-D).       PMT34950
      DELTAH= CTB*XS**0.666667                                          PMT34960
      GO TO 100                                                         PMT34970
C                                                                       PMT34980
C  PEAK PLUME RISE: BUOYANCY-DOMINATED PLUME, STABLE AIR (E,F).         PMT34990
   70 DELTAH= 2.6*(EFF*UINV*TA(ISCEN)/(9.8*DTDZ(ISC-4)))**0.333333      PMT35000
      GO TO 100                                                         PMT35010
C                                                                       PMT35020
C  PEAK PLUME RISE: MOMENTUM-DOMINATED PLUME, UNSTABLE AIR (A-D).       PMT35030
   80 CTMU= 1.89*(VP(IPS)*VP(IPS)*DP(IPS)*UINV/(VP(IPS)+3./UINV))**0.666PMT35040
     1667                                                               PMT35050
      DELTAH= DELHUM                                                    PMT35060
      GO TO 100                                                         PMT35070
C                                                                       PMT35080
C  PEAK PLUME RISE: MOMENTUM-DOMINATED PLUME, STABLE AIR (E,F).         PMT35090
C                                                                       PMT35100
   90 FACT=UINV*TA(ISCEN)/TP(IPS)                                       PMT35110
      DELTAH= 1.5*(0.5*VP(IPS)*DP(IPS))**0.666667*FACT**0.333333        PMT35120
     1 *(TA(ISCEN)/(DTDZ(ISC-4)*9.8))**0.166667                         PMT35130
      IF(DELHUM.LT.DELTAH) DELTAH=DELHUM                                PMT35140
C                                                                       PMT35150
  100 ESH(2)= HPRIME + DELTAH                                           PMT35160
      RETURN                                                            PMT35170
C                                                                       PMT35180
  200 IF(IBUOY.EQ.0) GO TO 210                                          PMT35190
C                                                                       PMT35200
C  DISTANCE-DEPENDENT PLUME RISE: BUOYANCY-DOMINATED PLUME,             PMT35210
C    ANY STABILITY (A-F).                                               PMT35220
      DELTAH= CTB*(DIST*1000.)**0.666667                                PMT35230
      ESH(1)=DELTAH + HPRIME                                            PMT35231
      IF(ESH(1).GT.ESH(2)) ESH(1)=ESH(2)                                PMT35240
      RETURN                                                            PMT35250
C                                                                       PMT35260
C  DISTANCE-DEPENDENT PLUME RISE: MOMENTUM-DOMINATED PLUME,             PMT35270
C    UNSTABLE AIR (A-D).                                                PMT35280
  210 IF(ISC.GE.5) GO TO 220                                            PMT35290
      DELTAH= CTMU*(DIST*1000.)**0.333333                               PMT35300
      ESH(1)=DELTAH + HPRIME                                            PMT35301
      IF(ESH(1).GT.ESH(2)) ESH(1)=ESH(2)                                PMT35310
      RETURN                                                            PMT35320
C                                                                       PMT35330
C  THERE IS NO DISTANCE-DEPENDENT PLUME RISE GIVEN FOR A                PMT35340
C    MOMENTUM-DOMINATED PLUME IN STABLE AIR. DISTANCE TO MAXIMUM PLUME  PMT35350
C    RISE FOR THIS SITUATION IS SET EQUAL TO ZERO IN THE MAIN PROGRAM,  PMT35360
C    SO THE MAXIMUM HEIGHT, ESH(2), IS USED AT ALL DISTANCES.           PMT35370
  220 ESH(1)=ESH(2)                                                     PMT35380
      RETURN                                                            PMT35390
C                                                                       PMT35400
      END                                                               PMT35410
C
C                                                                       PMT35420
C                                                                       PMT35430
C                                                                       PMT35440
      SUBROUTINE AUTGRD                                                 PMT35450
C                     SUBROUTINE AUTGRD , PART OF PEM-2 (VERSION 84130). PMT35460
C                                                                       PMT35470
C                                                                       PMT35480
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C     SUBROUTINE AUTGRID CALCULATES THE FIVE PARAMETERS DEFINING THE      PMT35490
C       RECEPTOR GRID (XSWC,YSWC,LX,LY,GRID) WHEN THE AUTOMATIC GRID      PMT35500
C       OPTION IS USED. THIS IS DONE BY SETTING GRID=0.0 IN THE INPUT     PMT35510
C       DATA. GRID PARAMETERS WILL BE CHOSEN FOR EACH SCENARIO SO AS      PMT35520
C       TO INSURE GOOD COVERAGE BY RECEPTORS NEAR THE POINT OF            PMT35530
C       MAXIMUM CONCENTRATION.  THIS POINT IS DETERMINED USING GAUSSIAN   PMT35540
C       PLUME ALGORITHMS WITHOUT POLLUTANT REMOVAL MECHANISMS.  THIS       PMT35550
C       POINT IS THEREFORE ONLY APPROXIMATE FOR PROBLEMS WHICH INCLUDE    PMT35560
C       DEPOSITION, SEDIMENTATION, AND CHEMICAL DECAY/TRANSFORMATION.     PMT35570
C       THE OPTIMUM RECEPTOR GRID IN THIS CASE SHOULD BE DETERMINED BY    PMT35580
C       TRIAL AND ERROR, USING THE RECEPTOR GRID DEFINED BY AUTGRD AS     PMT35590
C       THE FIRST APPROXIMATION.                                          PMT35600
C       NOTE THAT THE AUTOMATIC GRID OPTION CANNOT BE USED WHEN NTOPT>1 . PMT35610
C                                                                         PMT35620
C                                                                         PMT35630
C *** PEM-2 MODIFICATIONS BY K. SHANKAR RAO,                              PMT35640
C       NOAA-ATDL, OAK RIDGE, TENN.                                       PMT35650
C       APRIL 1984                                                        PMT35660
C                                                                         PMT35670
C                                                                         PMT35680
        COMMON/PEMCOM/CONC(50,50,2),SDF(50,50,2),TT(20),                  PMT35690
     1 XP(300),YP(300),EP(300,2),HP(300),DP(300),VP(300),TP(300),         PMT35700
     2 XA(50),YA(50),EA(50,2),SIZE(50),                                   PMT35710
     3 WD(24),WS(24),TA(24),HMIX(24),DTDZI(24),                           PMT35720
     4 AZ(6),BZ(6),CZ(6),P(6),SCLAB(6),DTDZ(2),SECTAN(16),                PMT35730
     5 XSWC,YSWC,GRID,LX,LY,A(2),B(2),POLNAM(3,2),CALNAM(7,2),            PMT35740
     6 ITA,IRD,IWR,IDSK,D80,D47,D8047,DIST,DELTA,HPRIME,                  PMT35750
     7 ESH(2),PEAK,IBUOY,IRISE,IDWN,EFF,XS,UINV,WVEC,                     PMT35760
     8 NAS,NPS,INDEX,IGRID,IAV,ISCEN,IWDOPT,IWD,ISC,IPS,                  PMT35770
     9 NTOPT,NWDOPT,NWSOPT,NWPOPT,NSCEN,NLIST,NARRAY,NTAPE,NCSOPT,        PMT35780
     * NMAX,NSTDWN,NPRISE,NINPEN,INTER,NPRINT,NGPR,NBID                   PMT35790
C                                                                         PMT35800
      COMMON/PARM2A/HAS,KSC,AA,BA,CA                                      PMT35810
      COMMON/PARM7A/HA,P1(6)                                              PMT35820
      DIMENSION XCRNR(4),YCRNR(4),HL(2),DL(2),XTM(2)                      PMT35830
C                                                                         PMT35840
C                                                                         PMT35850
      EPS=.005                                                            PMT35860
      NSTOP=100                                                           PMT35870
      AART2=SQRT(2.)*AA                                                   PMT35880
C                                                                         PMT35890
      E= 1.570796 -WVEC                                                   PMT35900
      SINEE= SIN(E)                                                       PMT35910
      COSNE= COS(E)                                                       PMT35920
      GX1= XP(1)*COSNE  + YP(1)*SINEE                                     PMT35930
      GX2= GX1                                                            PMT35940
      GY1= YP(1)*COSNE  - XP(1)*SINEE                                     PMT35950
      GY2= GY1                                                            PMT35960
      GX1=GX1+5.                                                          PMT35970
      GY1=GY1+5.                                                          PMT35980
      DO 200 I=1,NPS                                                      PMT35990
      XT= XP(I)*COSNE  + YP(I)*SINEE                                      PMT36000
      YT= YP(I)*COSNE  - XP(I)*SINEE                                      PMT36010
C                                                                         PMT36020
      UINV = 1./WS(ISCEN)                                                 PMT36030
      IF(NWPOPT.EQ.1) GO TO 165                                           PMT36040
      IF(HP(I).GT.10.) UINV = UINV*((10./HP(I))**P(ISC))                  PMT36050
      GO TO 166                                                           PMT36060
  165 IF(HP(I).GT.HA) UINV = UINV*((HA/HP(I)))**P1(ISC)                   PMT36070
  166 EFF= 2.45*VP(I)*DP(I)*DP(I)*(TP(I)-TA(ISCEN))/TP(I)                 PMT36080
C                                                                         PMT36090
      HL(1)= HP(I)                                                        PMT36100
      XSTAR1=HL(1)/AART2                                                  PMT36110
      CALL ROOT(XCMAX1,XSTAR1,EPS,NSTOP,IER)                              PMT36120
      DL(1)=.001*XCMAX1                                                   PMT36130
C                                                                         PMT36140
      IPS=I                                                               PMT36150
      IRISE=2                                                             PMT36160
      CALL RISE                                                           PMT36170
      HL(2)=ESH(2)                                                        PMT36180
      XSTAR2=HL(2)/AART2                                                PMT36190
      CALL ROOT(XCMAX2,XSTAR2,EPS,NSTOP,IER)                            PMT36200
      DL(2)=.001*XCMAX2                                                 PMT36210
C                                                                       PMT36220
      XTM(1)= XT + DL(1)                                                PMT36230
      XTM(2)= XT + DL(2)                                                PMT36240
      IF(XTM(2).GT.GX2) GX2= XTM(2)                                     PMT36250
      IF(XTM(1).LT.GX1) GX1= XTM(1)                                     PMT36260
      IF(YT.GT.GY2)     GY2= YT                                         PMT36270
      IF(YT.LT.GY1)     GY1= YT                                         PMT36280
  200 CONTINUE                                                          PMT36290
      XCRNR(1)= GX1                                                     PMT36300
      XCRNR(2)= GX2                                                     PMT36310
      XCRNR(3)= GX2                                                     PMT36320
      XCRNR(4)= GX1                                                     PMT36330
      YCRNR(1)= GY1                                                     PMT36340
      YCRNR(2)= GY1                                                     PMT36350
      YCRNR(3)= GY2                                                     PMT36360
      YCRNR(4)= GY2                                                     PMT36370
      DO 300 J=1,4                                                      PMT36380
      XCRNRT= XCRNR(J)                                                  PMT36390
      XCRNR(J)= XCRNR(J)*COSNE  - YCRNR(J)*SINEE                        PMT36400
  300 YCRNR(J)= YCRNR(J)*COSNE + XCRNRT*SINEE                           PMT36410
      XSWC= XCRNR(1)                                                    PMT36420
      XNEC= XSWC                                                        PMT36430
      YSWC= YCRNR(1)                                                    PMT36440
      YNEC= YSWC                                                        PMT36450
      DO 400 I=2,4                                                      PMT36460
      IF(XCRNR(I).GT.XNEC) XNEC= XCRNR(I)                               PMT36470
      IF(XCRNR(I).LT.XSWC) XSWC= XCRNR(I)                               PMT36480
      IF(YCRNR(I).GT.YNEC) YNEC= YCRNR(I)                               PMT36490
  400 IF(YCRNR(I).LT.YSWC) YSWC= YCRNR(I)                               PMT36500
      XT= XNEC - XSWC                                                   PMT36510
      YT= YNEC - YSWC                                                   PMT36520
      DMAX= XT                                                          PMT36530
      IF(YT.GT.XT) DMAX= YT                                             PMT36540
      IF(DMAX.LT.10.) GO TO 500                                         PMT36550
      IF(XT.GT.YT) GO TO 420                                            PMT36560
      LY=  50                                                           PMT36570
      GRID= YT/50.                                                      PMT36580
      LX= XT/GRID                                                       PMT36590
      IF(LX.LT.50) LX= LX+1                                             PMT36600
      GO TO 600                                                         PMT36610
  420 LX= 50                                                            PMT36620
      GRID= XT/50.                                                      PMT36630
      LY= YT/GRID                                                       PMT36640
      IF(LY.LT.50) LY=LY+1                                              PMT36650
      GO TO 600                                                         PMT36660
  500 IF(DMAX.LT.5.) GO TO 540                                          PMT36670
      GRID= 0.2                                                         PMT36680
      LX= XT/GRID                                                       PMT36690
      LY= YT/GRID                                                       PMT36700
      IF(LX.LT.50) LX=LX+1                                              PMT36710
      IF(LY.LT.50) LY=LY+1                                              PMT36720
      GO TO 600                                                         PMT36730
  540 IF(DMAX.LT.0.25) GO TO 580                                        PMT36740
      IF(XT.GT.YT) GO TO 560                                            PMT36750
      LY= 25                                                            PMT36760
      GRID= YT/25.                                                      PMT36770
      LX= XT/GRID                                                       PMT36780
      IF(LX.LT.25) LX=LX+1                                              PMT36790
      GO TO 600                                                         PMT36800
  560 LX= 25                                                            PMT36810
      GRID= XT/25.                                                      PMT36820
      LY= YT/GRID                                                       PMT36830
      IF(LY.LT.25) LY=LY+1                                              PMT36840
      GO TO 600                                                         PMT36850
  580 GRID= 0.01                                                        PMT36860
      LX= XT/GRID                                                       PMT36870
      LY= YT/GRID                                                       PMT36880
      IF(LX.LT.25) LX=LX+1
      IF(LY.LT.25) LY=LY+1
600   XSWC= XSWC - 0.5*GRID
      YSWC= YSWC - 0.5*GRID
      IF(NCSOPT.LT.1.OR.(LX.LE.25.AND.LY.LE.25)) GO TO 700
      XL=LX
      YL=LY
      IF(LX.GT.LY) GO TO 640
      DELG= YL/25.
      LY=25
      GRID= GRID*DELG
      LX= XL/DELG
      IF(LX.LT.25) LX=LX+1
      GO TO 700
640   DELG= XL/25.
      LX=25
      GRID= GRID*DELG
      LY= YL/DELG + 1.
700   CONTINUE
      WRITE(IWR,900)TT,ISCEN,IWDOPT
      XRSWC=XSWC+0.5*GRID
      YRSWC=YSWC+0.5*GRID
      WRITE(IWR,905)LX,LY,GRID,XRSWC,YRSWC
  900 FORMAT(1H1,37X,'POLLUTION EPISODIC MODEL (PEM-2)'///4X,'OUTPUT:  '
     1,20A4//4X,'AUTOMATICALLY GENERATED RECEPTOR GRID PARAMETERS FOR SC
     2ENARIO ',I2,'  (WIND DIRECTION SUB-SCENARIO ',I2,')'//)
905   FORMAT(4X,'RECEPTOR GRID CONSISTS OF ',I2,' COLUMNS AND ',I2,' ROW
     1S OF SPACING =',F7.4,' KM'//4X,'SOUTHWEST CORNER OF GRID =',F8.3,
     2' KM WEST,',F8.3,' KM SOUTH'/)
      RETURN
      END
C
C
C
      SUBROUTINE FUNR(X,R,FX,FPRIMX)
C                         SUBROUTINE FUNR , PART OF PEM-2 (VERSION 84130).
C
C
C     FUNR IS THE EXTERNAL SUBROUTINE CALLED IN SUBROUTINE ROOT.
C     FOR ANY GIVEN X, THIS SUBROUTINE DEFINES THE FUNCTION, F(X), AND
C     ITS FIRST DERIVATIVE WITH RESPECT TO X, FPRIM(X).
C     THESE FUNCTIONS ARE OF THE FORM: F(X)=P(X)*Q(X)-R, AND
C     FPRIM(X)=P(X)*DQDX(X)+Q(X)*DPDX(X)
C
C
C     PEM-2 PROGRAM DEVELOPMENT: JANUARY 1984
C     K. SHANKAR RAO
C     NOAA-ATDL, P.O. BOX-E
C     OAK RIDGE, TENN 37831
C
C
      COMMON/PARM2A/HAS,KSC,AA,BA,CA
C
C     STABILITY CLASS C
      IF(KSC.NE.3) GO TO 10
      PX=X*X
      DX=1.+.0004*X
      QX=(1.+.0003*X)/DX
      DPDX=2.*X
      DQDX=-.0001/(DX*DX)
      GO TO 25
C
C
   10 DX=1.+BA*X
      IF(KSC.GT.3) GO TO 15
C
C     STABILITY CLASSES A AND B
      PX=0.5*X*X*DX
      DPDX=X*(1.5*BA*X+1.)
      GO TO 20
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C     STABILITY CLASSES D,E, AND F
   15 PX=0.5*X*X/DX
      DPDX=0.5*X*(1.+DX)/(DX*DX)
C
C     ALL STABILITY CLASSES EXCEPT C
   20 TX1=1.+0.5*BA*X
      TX2=1.+.0002*X
      TX3=1.+.0004*X
      QX=1.+DX*TX2/(TX1*TX3)
      DQDX=(-.0002*DX*TX1+0.5*BA*TX2*TX3)/((TX1*TX3)**2)
C     ALL STABILITY CLASSES
C
   25 FX=PX*QX-R
      FPRIMX=PX*DQDX+QX*DPDX
C
      RETURN
      END
C
C
C
      SUBROUTINE ROOT(X,XSTAR,EPS,NSTOP,IER)
C                        SUBROUTINE ROOT , PART OF PEM-2 (VERSION 84130).
C
C     THIS SUBROUTINE FINDS THE ROOT OF A POLYNOMIAL EQUATION
C     F(X) = 0, USING THE NEWTON-RAPHSON ITERATION METHOD.
C     THIS SUBROUTINE IS CALLED IN SUBROUTINE AUTGRD TO
C     DETERMINE THE DOWNWIND DISTANCE TO MAXIMUM GROUND-LEVEL
C     CONCENTRATION FROM AN ELEVATED POINT-SOURCE PLUME.
C
C     X = ROOT OF EQUATION F(X)=0. (OUTPUT)
C     XSTAR = INITIAL GUESS OF VALUE OF X (INPUT)
C     EPS = UPPER BOUND OF ERROR IN X (INPUT)
C     NSTOP = MAXIMUM NO.OF ITERATION STEPS (INPUT)
C     IER = ERROR MESSAGE (OUTPUT)
C         = 0  NO ERROR
C         = 1  NO CONVERGENCE AFTER NSTOP ITERATIONS
C         = 2  FPRIM GOES TO ZERO AT SOME ITERATION STEP
C
C     PEM-2 PROGRAM DEVELOPMENT: JANUARY 1984
C     K. SHANKAR RAO
C     NOAA-ATDL, P.O. BOX-E
C     OAK RIDGE, TENN 37831
C
C
      COMMON/PARM2A/HAS,KSC,AA,BA,CA
C
C     INITIALIZATION
      IER=0
      X=XSTAR
      R=XSTAR*XSTAR
      XO=X
      CALL FUNR(XO,R,F,FPRIM)
      XOF=100.*EPS
C
C     START ITERATION LOOP
      DO 16 I=1,NSTOP
      IF(F) 11,16,11
C
C     EQUATION IS NOT SATISFIED BY X
   11 IF(FPRIM) 12,18,12
C
C     ITERATION IS IMPOSSIBLE
   12 DX=F/FPRIM
      X=X-DX
      XO=X
      CALL FUNR(XO,R,F,FPRIM)
C
C     TEST ON SATISFACTORY ACCURACY
      XO=EPS
      XABS=ABS(X)
      IF(XABS-1.) 14,14,13
   13 XO=XO*XABS
   14 IF(ABS(DX)-XO) 15,15,16
   15 IF(ABS(F)-XOF) 17,17,16
   16 CONTINUE
C     END ITERATION LOOP
C
C     NO CONVERGENCE AFTER NSTOP ITERATION STEPS ERROR RETURN
      IER=1
   17 RETURN
C
C     ERROR RETURN IN CASE OF ZERO DENOMINATOR
   18 IER=2
      RETURN
      END
C
C
C
      BLOCK DATA
C                                 BLOCK DATA , PART OF PEM-2 (VERSION 84130).
C
C
C
C     THIS SUBPROGRAM INITIALIZES VARIABLES IN COMMON/PEMCOM/
C
C *** PEM MODIFICATIONS BY M.M.STEVENS,
C     NOAA-ATDL, P.O.BOX-E, OAK RIDGE, TENN 37831
C     DECEMBER 1982
C *** PEM-2 MODIFICATIONS BY K. SHANKAR RAO,
C     DECEMBER 1983
C
C
      COMMON/PEMCOM/CONC(50,50,2),SDF(50,50,2),TT(20),
     1 XP(300),YP(300),EP(300,2),HP(300),DP(300),VP(300),TP(300),
     2 XA(50),YA(50),EA(50,2),SIZE(50),
     3 WD(24),WS(24),TA(24),HMIX(24),DTDZI(24),
     4 AZ(6),BZ(6),CZ(6),P(6),SCLAB(6),DTDZ(2),SECTAN(16),
     5 XSWC,YSWC,GRID,LX,LY,A(2),B(2),POLNAM(3,2),CALNAM(7,2),
     6 ITA,IRD,IWR,IDSK,D80,D47,D8047,DIST,DELTA,HPRIME,
     7 ESH(2),PEAK,IBUOY,IRISE,IDWN,EFF,XS,UINV,WVEC,
     8 NAS,NPS,INDEX,IGRID,IAV,ISCEN,IWDOPT,IWD,ISC,IPS,
     9 NTOPT,NWDOPT,NWSOPT,NWPOPT,NSCEN,NLIST,NARRAY,NTAPE,NCSOPT,
     * NMAX,NSTDWN,NPRISE,NINPEN,INTER,NPRINT,NGPR,NBID
C
C
      DATA INDEX,NAS,NPS/0,0,0/
      DATA ITA,IRD,IWR,IDSK/1,5,6,8/
      DATA SCLAB/2HA ,2HB ,2HC ,2HD ,2HE ,2HF /
      DATA P/0.15,0.15,0.2,0.25,0.3,0.3/
      DATA AZ/.24,.24,.20,.14,.08,.08/
      DATA BZ/.001,.001,0.,.0003,.0015,.0015/
      DATA CZ/.001,.001,0.,0.,0.,0./
      DATA SECTAN/0.,.39270,.78540,1.17810,1.57080,1.96350,2.35620,
     1 2.74890,3.14159,3.53429,3.92699,4.31969,4.71239,5.10509,
     2 5.49779,5.89049/
C
      END
C
C
C
C
      SUBROUTINE XINTEG(XL,XU,EPS,NDIM,FCT,Y,IER,AUX)
C                         SUBROUTINE XINTEG , PART OF PEM-2 (VERSION 84130).
        REAL*8 FCT
C     FOR UNIVAC-1100
      REAL*8 XL,XU,X,Y
C
      DIMENSION AUX(1)
C
```

```
C                                                                       PMT38950
C     THIS SUBROUTINE PERFORMS NUMERICAL INTEGRATION OF AN EXTERNALLY   PMT38960
C     DEFINED FUNCTION OVER A FINITE INTERVAL USING THE TRAPEZOIDAL RULEPMT38970
C     WITH ROMBERG EXTRAPOLATION.  THIS ROUTINE IS CALLED IN THE MAIN   PMT38980
C     PROGRAM FOR NUMERICAL INTEGRATIONS W.R.T. X FOR AREA SOURCES.     PMT38990
C                                                                       PMT39000
C     XL = LOWER LIMIT OF INTEGRATION INTERVAL. (INPUT)                 PMT39010
C     XU = UPPER LIMIT OF INTEGRATION INTERVAL. (INPUT)                 PMT39020
C     EPS = UPPER BOUND FOR RELATIVE ERROR BETWEEN SUCCESSIVE           PMT39030
C            APPROXIMATIONS TO THE INTEGRAL. (INPUT)                    PMT39040
C     NDIM = MAXIMUM NO.OF BISECTIONS OF INTERVAL (XL,XU). (INPUT)      PMT39050
C     FCT = EXTERNALLY DEFINED INTEGRAND FUNCTION. (INPUT)              PMT39060
C     Y = BEST POSSIBLE APPROXIMATION OF INTEGRAL. (OUTPUT)             PMT39070
C     IER = ERROR MESSAGE (OUTPUT)                                      PMT39080
C         = 0  NO ERROR                                                 PMT39090
C         = 1  SPECIFIED ACCURACY CANT BE REACHED DUE TO ROUNDING ERRORSPMT39100
C         = 2  IMPOSSIBLE TO CHECK ACCURACY (IF NDIM<5) OR SPECIFIED    PMT39110
C              ACCURACY CAN'T BE REACHED. NDIM SHOULD BE INCREASED.     PMT39120
C     AUX = AUXILIARY STORAGE ARRAY WITH DIMENSION NDIM. (INTERNAL)     PMT39130
C                                                                       PMT39140
C     PEM-2 PROGRAM DEVELOPMENT: DECEMBER 1983                          PMT39150
C     K. SHANKAR RAO                                                    PMT39160
C     NOAA-ATDL, P.O. BOX-E                                             PMT39170
C     OAK RIDGE, TENN 37831                                             PMT39180
C                                                                       PMT39190
C                                                                       PMT39200
C     PREPARATIONS FOR ROMBERG-LOOP                                     PMT39210
      AUX(1)=.5*(FCT(XL)+FCT(XU))                                       PMT39220
      H=XU-XL                                                           PMT39230
      IF(NDIM-1) 8,8,1                                                  PMT39240
    1 IF(H) 2,10,2                                                      PMT39250
C                                                                       PMT39260
C     NDIM IS GREATER THAN 1 AND H IS NOT EQUAL TO 0.                   PMT39270
    2 HH=H                                                              PMT39280
      EPSREL=EPS                                                        PMT39290
      EPSA=1.0E-10                                                      PMT39300
      DELT2=1.E06                                                       PMT39310
      P=1.                                                              PMT39320
      JJ=1                                                              PMT39330
C                                                                       PMT39340
C                                                                       PMT39350
      DO 7 I=2,NDIM                                                     PMT39360
      Y=AUX(1)                                                          PMT39370
      DELT1=DELT2                                                       PMT39380
      HD=HH                                                             PMT39390
      HH=0.5*HH                                                         PMT39400
      P=.5*P                                                            PMT39410
      X=XL+HH                                                           PMT39420
      SUM=0.                                                            PMT39430
C                                                                       PMT39440
C                                                                       PMT39450
      DO 3 J=1,JJ                                                       PMT39460
      SUM=SUM+FCT(X)                                                    PMT39470
    3 X=X+HD                                                            PMT39480
      AUX(I)=.5*AUX(I-1)+P*SUM                                          PMT39490
C                                                                       PMT39500
C     A NEW APPROXIMATION OF INTEGRAL VALUE IS COMPUTED BY MEANS OF     PMT39510
C     TRAPEZOIDAL RULE.                                                 PMT39520
C                                                                       PMT39530
C     START OF ROMBERG EXTRAPOLATION METHOD.                            PMT39540
      Q=1.                                                              PMT39550
      IM1=I-1                                                           PMT39560
      DO 4 J=1,IM1                                                      PMT39570
      II=I-J                                                            PMT39580
      Q=Q+Q                                                             PMT39590
      Q=Q+Q                                                             PMT39600
    4 AUX(II)=AUX(II+1)+(AUX(II+1)-AUX(II))/(Q-1.)                      PMT39610
C     END OF ROMBERG-STEP                                               PMT39620
C     FINAL VALUE OF AUX(II)=AUX(1) WHICH CONTAINS VALUE OF             PMT39630
C     INTEGRAL FOR THIS APPROXIMATION.                                  PMT39640
```

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C
C     TESTS FOR CONVERGENCE
      IF(Y.GT.EPSA) DELT2=ABS(Y-AUX(1))/Y
      IF(Y.LE.EPSA) DELT2=0.
      IF(I-2) 7,5,5
    5 IF(DELT2-EPSREL) 10,10,6
    6 IF(DELT2-DELT1) 7,11,11
    7 JJ=JJ+JJ
C     END LOOP ON APPROXIMATIONS
C
C
    8 IER=2
    9 Y=H*AUX(1)
      RETURN
C
C
   10 IER=0
      GO TO 9
C
C
   11 IER=1
      Y=H*Y
      RETURN
      END
C
C
C
C
C
      SUBROUTINE D01AJF(F, A, B, EPSABS, EPSREL, RESULT, ABSERR,WORK,
     * LWORK, IWORK, LIWORK, IFAIL)
C                      SUBROUTINE D01AJF , PART OF PEM-2 (VERSION 84130).
C
C     MARK 8 RELEASE. NAG COPYRIGHT 1980
C
C     D01AJF IS A GENERAL PURPOSE INTEGRATOR WHICH CALCULATES
C     AN APPROXIMATION TO THE INTEGRAL OF A FUNCTION OVER A FINITE
C     INTERVAL (A,B).  THIS ROUTINE CAN BE USED WHEN THE INTEGRAND
C     HAS SINGULARITIES, ESPECIALLY WHEN THESE ARE OF ALGEBRAIC OR
C     LOGARITHMIC TYPE.  D01AJF IS AN ADAPTIVE ROUTINE, USING THE
C     GAUSS 10-POINT AND KRONROD 21-POINT RULES.  THE ALGORITHM
C     INCORPORATES A GLOBAL ACCEPTANCE CRITERION TOGETHER WITH
C     EPS-ALGORITHM TO PERFORM EXTRAPOLATION.  THE LOCAL ERROR IS
C     ESTIMATED.
C
C     THE GENERAL PURPOSE INTEGRATOR D01AJF INCLUDES THE FOLLOWING:
C     SUBROUTINES (1) D01AJF, (2) D01AJV, (3) D01AJX, (4) D01AJY,
C     (5) D01AJZ, INTEGER FUNCTION P01AAF, DOUBLE PRECISION FUNCTIONS
C     (1) X02AAF, (2) X02ABF, (3) X02ACF, AND SUBROUTINE X04AAF.
C     THE PROGRAM LISTINGS FOR THESE SUBROUTINES AND FUNCTIONS, COPIED
C     HERE FROM ORNL - NAG LIBRARY, FOLLOW.  THESE ARE DEVELOPED BY
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C     WHICH HOLDS THE COPYRIGHT (NAG FORTRAN MINI MANUAL, MARK8, 1980).
C     THESE PROGRAM LISTINGS ARE INCLUDED HERE WITH THEIR KIND
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C           OAK RIDGE, TENNESSEE 37831
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C     PROGRAMS SHOULD NOT BE USED FOR ANY OTHER PURPOSE WITHOUT PRIOR
C     APPROVAL FROM NAG AND ORNL.
C
C
C     D01AJF ITSELF IS ESSENTIALLY A DUMMY ROUTINE WHOSE FUNCTION IS TO
C     PARTITION THE WORK ARRAYS WORK AND IWORK FOR USE BY D01AJV.
C     WORK IS PARTITIONED INTO 4 ARRAYS EACH OF SIZE LWORK/4.
C     IWORK IS A SINGLE ARRAY IN D01AJV.
C
```

```
C     .. SCALAR ARGUMENTS ..
      DOUBLE PRECISION A, ABSERR, B, EPSABS, EPSREL, RESULT
      INTEGER IFAIL, LIWORK, LWORK
C     .. ARRAY ARGUMENTS ..
      DOUBLE PRECISION WORK(LWORK)
      INTEGER IWORK(LIWORK)
C     .. FUNCTION ARGUMENTS ..
      DOUBLE PRECISION F
C     ..
C     .. LOCAL SCALARS ..
C$P 1
      DOUBLE PRECISION SRNAME
      INTEGER IBL, IEL, IER, IRL, LIMIT
C     .. FUNCTION REFERENCES ..
      INTEGER P01AAF
C     .. SUBROUTINE REFERENCES ..
C     D01AJV
C     ..
      EXTERNAL F
      DATA SRNAME /8H D01AJF /
C     CHECK THAT MINIMUM WORKSPACE REQUIREMENTS ARE MET
      IF (LWORK.LT.4) GO TO 20
      IF (LIWORK.LT.LWORK/8+2) GO TO 20
C     LIMIT = UPPER BOUND ON NUMBER OF SUBINTERVALS
      LIMIT = LWORK/4
C     SET UP BASE ADDRESSES FOR WORK ARRAYS
      IBL = LIMIT + 1
      IEL = LIMIT + IBL
      IRL = LIMIT + IEL
C     PERFORM INTEGRATION
      CALL D01AJV(F, A, B, DABS(EPSABS), DABS(EPSREL), WORK(1),WORK(IBL)
     *, WORK(IEL), WORK(IRL), LIMIT, IWORK, LIWORK,RESULT, ABSERR, IER)
      IF (IER.NE.0) GO TO 40
      IFAIL = 0
      GO TO 60
C     ERROR 6 = INSUFFICIENT WORKSPACE
   20 IER = 6
   40 IFAIL = P01AAF(IFAIL,IER,SRNAME)
   60 RETURN
      END
C
C
C
      SUBROUTINE D01AJV(F, A, B, EPSABS, EPSREL, ALIST, BLIST,ELIST,
     * RLIST, LIMIT, IORD, LIORD, RESULT, ABSERR, IER)
C                    SUBROUTINE D01AJV , PART OF PEM-2 (VERSION 84130).
C
C     MARK 8 RELEASE. NAG COPYRIGHT 1979
C     BASED ON QUADPACK ROUTINE DQAGS (FORMERLY QAGS)
C     ****************************************************************
C
C        PURPOSE
C           THE ROUTINE CALCULATES AN APPROXIMATION
C           /RESULT/ TO A GIVEN DEFINITE INTEGRAL   I =
C           INTEGRAL OF /F/ OVER (A,B), HOPEFULLY
C           SATISFYING FOLLOWING CLAIM FOR ACCURACY .
C           ABS(I-RESULT) .LE. MAX(EPSABS,EPSREL*ABS(I)).
C
C         CALLING SEQUENCE
C           CALL D01AJV (F,A,B,EPSABS,EPSREL,ALIST,BLIST,ELIST,
C                        RLIST,LIMIT,IORD,LIORD,RESULT,ABSERR,IER)
C
C        PARAMETERS
C            F       - FUNCTION SUBPROGRAM DEFINING THE INTEGRAND
C                      FUNCTION F(X). THE ACTUAL NAME FOR F
C                      NEEDS TO BE DECLARED E X T E R N A L
C                      IN THE DRIVER PROGRAM
C
C            A       - LOWER LIMIT OF INTEGRATION
C
```

```
C     B      - UPPER LIMIT OF INTEGRATION                               PMT41030
C                                                                       PMT41040
C     EPSABS - ABSOLUTE ACCURACY REQUESTED                              PMT41050
C                                                                       PMT41060
C     EPSREL - RELATIVE ACCURACY REQUESTED                              PMT41070
C                                                                       PMT41080
C     ALIST,BLIST,ELIST,RLIST                                           PMT41090
C            - WORK ARRAYS (FUNCTIONS DESCRIBED BELOW)                  PMT41100
C                                                                       PMT41110
C     LIMIT  - UPPER BOUND FOR NUMBER OF SUBINTERVALS                   PMT41120
C                                                                       PMT41130
C     IORD   - WORK ARRAY                                               PMT41140
C                                                                       PMT41150
C     LIORD  - LENGTH OF IORD (AT LEAST LIMIT/2 + 2)                    PMT41160
C                                                                       PMT41170
C     RESULT - APPROXIMATION TO THE INTEGRAL                            PMT41180
C                                                                       PMT41190
C     ABSERR - ESTIMATE OF THE MODULUS OF THE ABSOLUTE ERROR,           PMT41200
C              WHICH SHOULD EQUAL OR EXCEED ABS(I-RESULT)               PMT41210
C                                                                       PMT41220
C     IER    - IER   = 0 NORMAL AND RELIABLE                            PMT41230
C                        TERMINATION OF THE ROUTINE.                    PMT41240
C                        IT IS ASSUMED THAT THE                         PMT41250
C                        REQUESTED  ACCURACY HAS BEEN                   PMT41260
C                        ACHIEVED.                                      PMT41270
C            - IER   .NE. 0 ABNORMAL TERMINATION OF                     PMT41280
C                        THE ROUTINE. THE ESTIMATES                     PMT41290
C                        FOR INTEGRAL AND ERROR ARE                     PMT41300
C                        LESS RELIABLE. IT IS ASSUMED                   PMT41310
C                        THAT THE  REQUESTED ACCURACY                   PMT41320
C                        HAS NOT BEEN ACHIEVED.                         PMT41330
C                    = 1 MAXIMUM NUMBER OF SUBDIVISIONS ALLOWED         PMT41340
C                        HAS BEEN ACHIEVED. THE USER CAN                PMT41350
C                        ALLOW MORE SUB DIVISIONS BY                    PMT41360
C                        INCREASING THE DIMENSIONS OF THE               PMT41370
C                        WORK ARRAYS WORK AND IWORK.                    PMT41380
C                        HOWEVER, THIS MAY                              PMT41390
C                        YIELD NO  IMPROVEMENT, AND IT                  PMT41400
C                        IS RATHER ADVISED TO HAVE A                    PMT41410
C                        CLOSE LOOK AT THE INTEGRAND,                   PMT41420
C                        IN ORDER TO DETERMINE THE                      PMT41430
C                        INTEGRATION  DIFFICULTIES. IF                  PMT41440
C                        THE POSITION OF A LOCAL                        PMT41450
C                        DIFFICULTY CAN BE DETERMINED                   PMT41460
C                        (I.E.  SINGULARITY,                            PMT41470
C                        DISCONTINUITY WITHIN THE                       PMT41480
C                        INTERVAL) ONE WILL PROBABLY                    PMT41490
C                        GAIN FROM  SPLITTING UP THE                    PMT41500
C                        INTERVAL AT THIS POINT AND                     PMT41510
C                        CALLING THE INTEGRATOR ON THE                  PMT41520
C                        SUB-RANGES. IF POSSIBLE, AN                    PMT41530
C                        APPROPRIATE SPECIAL-PURPOSE                    PMT41540
C                        INTEGRATOR SHOULD BE USED                      PMT41550
C                        WHICH IS DESIGNED FOR                          PMT41560
C                        HANDLING THE TYPE  OF                          PMT41570
C                        DIFFICULTY INVOLVED.                           PMT41580
C                    = 2 THE OCCURRENCE OF ROUNDOFF                     PMT41590
C                        ERROR IS DETECTED WHICH                        PMT41600
C                        PREVENTS THE REQUESTED                         PMT41610
C                        TOLERANCE  FROM BEING                          PMT41620
C                        ACHIEVED. THE ERROR MAY BE                     PMT41630
C                        UNDER-ESTIMATED.                               PMT41640
C                    = 3 EXTREMELY BAD INTEGRAND BEHAVIOUR              PMT41650
C                        OCCURS AT SOME INTERIOR POINTS OF THE          PMT41660
C                        INTEGRATION INTERVAL.                          PMT41670
C                    = 4 IT IS PRESUMED THAT THE REQUESTED              PMT41680
C                        TOLERANCE CANNOT BE ACHIEVED,                  PMT41690
C                        AND THAT THE RETURNED RESULT                   PMT41700
C                        IS THE BEST WHICH CAN BE                       PMT41710
C                        OBTAINED.                                      PMT41720
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C                        = 5 THE INTEGRAL IS PROBABLY DIVERGENT, OR      PMT41730
C                            SLOWLY CONVERGENT. IT MUST BE NOTED         PMT41740
C                            THAT DIVERGENCY CAN OCCUR                   PMT41750
C                            WITH ANY OTHER VALUE OF IER.                PMT41760
C                                                                        PMT41770
C     ******************************************************             PMT41780
C     .. SCALAR ARGUMENTS ..                                             PMT41790
      DOUBLE PRECISION A, ABSERR, B, EPSABS, EPSREL, RESULT              PMT41800
      INTEGER IER, LIMIT, LIORD                                          PMT41810
C     .. ARRAY ARGUMENTS ..                                              PMT41820
      DOUBLE PRECISION ALIST(LIMIT), BLIST(LIMIT), ELIST(LIMIT),         PMT41830
     * RLIST(LIMIT)                                                      PMT41840
      INTEGER IORD(LIORD)                                                PMT41850
C     .. FUNCTION ARGUMENTS ..                                           PMT41860
      DOUBLE PRECISION F                                                 PMT41870
C     ..                                                                 PMT41880
C     .. SCALARS IN COMMON ..                                            PMT41890
      INTEGER JUPBND                                                     PMT41900
C     ..                                                                 PMT41910
C     .. LOCAL SCALARS ..                                                PMT41920
      DOUBLE PRECISION A1, A2, ABSEPS, AREA12, AREA1, AREA2, AREA, B1,   PMT41930
     * B2,CORREC, DEFAB1, DEFAB2, DEFABS, DRES, EPMACH, ERLARG,ERLAST,   PMT41940
     * ERRBND, ERRMAX, ERRO12, ERROR1, ERROR2, ERRSUM,ERTEST, OFLOW,     PMT41950
     * RESABS, RESEPS, SMALL, UFLOW                                      PMT41960
      INTEGER ID, IERRO, IROFF1, IROFF2, IROFF3, K, KSGN, KTMIN,LAST1,   PMT41970
     * LAST, MAXERR, NRES, NRMAX, NUMRL2                                 PMT41980
      LOGICAL EXTRAP, NOEXT                                              PMT41990
C     .. LOCAL ARRAYS ..                                                 PMT42000
      DOUBLE PRECISION RES3LA(3), RLIST2(52)                             PMT42010
C     .. FUNCTION REFERENCES ..                                          PMT42020
      DOUBLE PRECISION X02AAF, X02ABF, X02ACF                            PMT42030
C     .. SUBROUTINE REFERENCES ..                                        PMT42040
C     D01AJX, D01AJY, D01AJZ                                             PMT42050
C     ..                                                                 PMT42060
      EXTERNAL F                                                         PMT42070
      COMMON /AD01AJ/ JUPBND                                             PMT42080
C                                                                        PMT42090
C            THE DIMENSION OF /RLIST2/ IS DETERMINED BY                  PMT42100
C            DATA /LIMEXP/ IN SUBROUTINE D01AJY (/RLIST2/                PMT42110
C            SHOULD BE OF DIMENSION (LIMEXP+2) AT LEAST).                PMT42120
C                                                                        PMT42130
      EPMACH = X02AAF()                                                  PMT42140
      UFLOW = X02ABF()                                                   PMT42150
      OFLOW = X02ACF()                                                   PMT42160
C                                                                        PMT42170
C            LIST OF MAJOR VARIABLES                                     PMT42180
C            -----------------------                                     PMT42190
C                                                                        PMT42200
C           ALIST     - LIST OF LEFT END-POINTS OF ALL SUBINTERVALS      PMT42210
C                       CONSIDERED UP TO NOW                             PMT42220
C                                                                        PMT42230
C           BLIST     - LIST OF RIGHT END-POINTS OF ALL SUBINTERVALS     PMT42240
C                       CONSIDERED UP TO NOW                             PMT42250
C                                                                        PMT42260
C           RLIST(I)  - APPROXIMATION TO THE INTEGRAL OVER               PMT42270
C                       (ALIST(I),BLIST(I))                              PMT42280
C                                                                        PMT42290
C           RLIST2    - ARRAY OF DIMENSION AT LEAST LIMEXP+2             PMT42300
C                       CONTAINING THE PART OF THE EPSILON TABLE         PMT42310
C                       WHICH IS STILL NEEDED FOR FURTHER                PMT42320
C                       COMPUTATIONS                                     PMT42330
C                                                                        PMT42340
C           ELIST(I)  - ERROR ESTIMATE APPLYING TO RLIST(I)              PMT42350
C                                                                        PMT42360
C           MAXERR    - POINTER TO THE INTERVAL WITH LARGEST ERROR       PMT42370
C                       ESTIMATE                                         PMT42380
C                                                                        PMT42390
C           ERRMAX    - ELIST(MAXERR)                                    PMT42400
C                                                                        PMT42410
C           ERLAST    - ERROR ON THE INTERVAL CURRENTLY SUBDIVIDED       PMT42420
```

```
C                 (BEFORE THAT SUBDIVISION HAS TAKEN PLACE)
C
C           AREA      - SUM OF THE INTEGRALS OVER THE SUBINTERVALS
C
C           ERRSUM    - SUM OF THE ERRORS OVER THE SUBINTERVALS
C
C           ERRBND    - REQUESTED ACCURACY MAX(EPSABS,EPSREL*
C                       ABS(RESULT))
C
C           *****1    - VARIABLE FOR THE LEFT INTERVAL
C
C           *****2    - VARIABLE FOR THE RIGHT INTERVAL
C
C           LAST      - INDEX FOR SUBDIVISION
C
C           NRES      - NUMBER OF CALLS TO THE EXTRAPOLATION ROUTINE
C
C           NUMRL2    - NUMBER OF ELEMENTS CURRENTLY  IN
C                       RLIST2. IF AN APPROPRIATE
C                       APPROXIMATION TO THE COMPOUNDED
C                       INTEGRAL HAS BEEN OBTAINED IT IS
C                       PUT IN  RLIST2(NUMRL2) AFTER NUMRL2
C                       HAS BEEN INCREASED BY ONE.
C
C           SMALL     - LENGTH OF THE SMALLEST INTERVAL CONSIDERED
C                       UP TO NOW, MULTIPLIED BY 1.5
C
C           ERLARG    - SUM OF THE ERRORS OVER THE INTERVALS LARGER
C                       THAN THE SMALLEST INTERVAL
C                       CONSIDERED UP TO NOW
C           EXTRAP    - LOGICAL VARIABLE DENOTING THAT THE
C                       ROUTINE IS ATTEMPTING TO PERFORM
C                       EXTRAPOLATION.  I.E. BEFORE
C                       SUBDIVIDING THE SMALLEST INTERVAL
C                       WE TRY TO DECREASE THE VALUE OF
C                       ERLARG
C           NOEXT     - LOGICAL VARIABLE DENOTING THAT EXTRAPOLATION
C                       IS NO LONGER ALLOWED(/TRUE/ VALUE)
C
C           FIRST APPROXIMATION TO THE INTEGRAL
C           -----------------------------------
C
      LAST1 = 1
      IER = 0
      IERRO = 0
      CALL D01AJZ(F, A, B, RESULT, ABSERR, DEFABS, RESABS)
C
C           TEST ON ACCURACY
C
      DRES = DABS(RESULT)
      ERRBND = DMAX1(EPSABS,EPSREL*DRES)
      IF (ABSERR.LE.1.0D+02*EPMACH*DEFABS .AND. ABSERR.GT.ERRBND)IER = 2
      IF (LIMIT.LT.2 .AND. ABSERR.GT.ERRBND) IER = 1
      IF (IER.NE.0 .OR. ABSERR.LE.ERRBND) GO TO 320
C
C           INITIALIZATION
C           --------------
C
      ALIST(1) = A
      BLIST(1) = B
      RLIST(1) = RESULT
      RLIST2(1) = RESULT
      ERRMAX = ABSERR
      MAXERR = 1
      AREA = RESULT
      ERRSUM = ABSERR
      ABSERR = OFLOW
      NRMAX = 1
      NRES = 0
      NUMRL2 = 2
      KTMIN = 0                                                         PMT43130
      EXTRAP = .FALSE.                                                  PMT43140
      NOEXT = .FALSE.                                                   PMT43150
      IROFF1 = 0                                                        PMT43160
      IROFF2 = 0                                                        PMT43170
      IROFF3 = 0                                                        PMT43180
      KSGN = -1                                                         PMT43190
      IF (DRES.GE.(0.1D+01-0.5D+02*EPMACH)*DEFABS) KSGN = 1             PMT43200
C                                                                       PMT43210
C           MAIN DO-LOOP                                                PMT43220
C           ------------                                                PMT43230
C                                                                       PMT43240
      IF (LIMIT.LT.2) GO TO 220                                         PMT43250
      DO 200 LAST=2,LIMIT                                               PMT43260
C                                                                       PMT43270
C           BISECT THE SUBINTERVAL WITH THE NRMAX-TH LARGEST            PMT43280
C           ERROR ESTIMATE                                              PMT43290
C                                                                       PMT43300
         LAST1 = LAST                                                   PMT43310
         A1 = ALIST(MAXERR)                                             PMT43320
         B1 = 0.5D+00*(ALIST(MAXERR)+BLIST(MAXERR))                     PMT43330
         A2 = B1                                                        PMT43340
         B2 = BLIST(MAXERR)                                             PMT43350
         ERLAST = ERRMAX                                                PMT43360
         CALL D01AJZ(F, A1, B1, AREA1, ERROR1, RESABS, DEFAB1)          PMT43370
         CALL D01AJZ(F, A2, B2, AREA2, ERROR2, RESABS, DEFAB2)          PMT43380
C                                                                       PMT43390
C           IMPROVE PREVIOUS APPROXIMATION OF INTEGRAL                  PMT43400
C           AND ERROR AND TEST FOR ACCURACY                             PMT43410
C                                                                       PMT43420
         AREA12 = AREA1 + AREA2                                         PMT43430
         ERRO12 = ERROR1 + ERROR2                                       PMT43440
         ERRSUM = ERRSUM + ERRO12 - ERRMAX                              PMT43450
         AREA = AREA + AREA12 - RLIST(MAXERR)                           PMT43460
         IF (DEFAB1.EQ.ERROR1 .OR. DEFAB2.EQ.ERROR2) GO TO 40           PMT43470
         IF (DABS(RLIST(MAXERR)-AREA12).GT.0.1D-04*DABS(AREA12) .OR.    PMT43480
     *   ERRO12.LT.0.99D+00*ERRMAX) GO TO 20                            PMT43490
         IF (EXTRAP) IROFF2 = IROFF2 + 1                                PMT43500
         IF (.NOT.EXTRAP) IROFF1 = IROFF1 + 1                           PMT43510
   20    IF (LAST.GT.10 .AND. ERRO12.GT.ERRMAX) IROFF3 = IROFF3 + 1     PMT43520
   40    RLIST(MAXERR) = AREA1                                          PMT43530
         RLIST(LAST) = AREA2                                            PMT43540
         ERRBND = DMAX1(EPSABS,EPSREL*DABS(AREA))                       PMT43550
         IF (ERRSUM.LE.ERRBND) GO TO 280                                PMT43560
C                                                                       PMT43570
C           TEST FOR ROUNDOFF ERROR AND EVENTUALLY                      PMT43580
C           SET ERROR FLAG                                              PMT43590
C                                                                       PMT43600
         IF (IROFF1+IROFF2.GE.10 .OR. IROFF3.GE.20) IER = 2             PMT43610
         IF (IROFF2.GE.5) IERRO = 3                                     PMT43620
C                                                                       PMT43630
C           SET ERROR FLAG IN THE CASE THAT THE NUMBER OF INTERVAL      PMT43640
C            BISECTIONS EXCEEDS /LIMIT/                                 PMT43650
C                                                                       PMT43660
         IF (LAST.EQ.LIMIT) IER = 1                                     PMT43670
C                                                                       PMT43680
C           SET ERROR FLAG IN THE CASE OF BAD INTEGRAND BEHAVIOUR       PMT43690
C           AT INTERIOR POINTS OF INTEGRATION RANGE                     PMT43700
C                                                                       PMT43710
         IF (DMAX1(DABS(A1),DABS(B2)).LE.(0.1D+01+0.1D+03*EPMACH)*      PMT43720
     *   (DABS(A2)+0.1D+04*UFLOW)) IER = 4                              PMT43730
         IF (IER.NE.0) GO TO 220                                        PMT43740
C                                                                       PMT43750
C           APPEND THE NEWLY-CREATED INTERVALS TO THE LIST              PMT43760
C                                                                       PMT43770
         IF (ERROR2.GT.ERROR1) GO TO 60                                 PMT43780
         ALIST(LAST) = A2                                               PMT43790
         BLIST(MAXERR) = B1                                             PMT43800
         BLIST(LAST) = B2                                               PMT43810
         ELIST(MAXERR) = ERROR1                                         PMT43820
      ELIST(LAST) = ERROR2                                              PMT43830
      GO TO 80                                                          PMT43840
   60 ALIST(MAXERR) = A2                                                PMT43850
      ALIST(LAST) = A1                                                  PMT43860
      BLIST(LAST) = B1                                                  PMT43870
      RLIST(MAXERR) = AREA2                                             PMT43880
      RLIST(LAST) = AREA1                                               PMT43890
      ELIST(MAXERR) = ERROR2                                            PMT43900
      ELIST(LAST) = ERROR1                                              PMT43910
C                                                                       PMT43920
C        CALL SUBROUTINE D01AJX TO MAINTAIN THE                         PMT43930
C        DESCENDING ORDERING IN THE LIST OF ERROR                       PMT43940
C        ESTIMATES AND SELECT THE SUBINTERVAL WITH                      PMT43950
C        NRMAX-TH LARGEST ERROR ESTIMATE (TO BE BISECTED                PMT43960
C        NEXT)                                                          PMT43970
C                                                                       PMT43980
   80 CALL D01AJX(LIMIT, LAST, MAXERR, ERRMAX, ELIST, IORD,LIORD,       PMT43990
     * NRMAX)                                                           PMT44000
      IF (LAST.EQ.2) GO TO 180                                          PMT44010
      IF (NOEXT) GO TO 200                                              PMT44020
      ERLARG = ERLARG - ERLAST                                          PMT44030
      IF (DABS(B1-A1).GT.SMALL) ERLARG = ERLARG + ERRO12                PMT44040
      IF (EXTRAP) GO TO 100                                             PMT44050
C                                                                       PMT44060
C        TEST WHETHER THE INTERVAL TO BE BISECTED NEXT IS THE           PMT44070
C        SMALLEST INTERVAL                                              PMT44080
C                                                                       PMT44090
      IF (DABS(BLIST(MAXERR)-ALIST(MAXERR)).GT.SMALL) GO TO 200         PMT44100
      EXTRAP = .TRUE.                                                   PMT44110
      NRMAX = 2                                                         PMT44120
  100 IF (IERRO.EQ.3 .OR. ERLARG.LE.ERTEST) GO TO 140                   PMT44130
C                                                                       PMT44140
C        THE SMALLEST INTERVAL HAS THE LARGEST ERROR.                   PMT44150
C        BEFORE BISECTING DECREASE THE SUM OF THE ERRORS                PMT44160
C        OVER THE LARGER INTERVALS(ERLARG) AND PERFORM                  PMT44170
C        EXTRAPOLATION                                                  PMT44180
C                                                                       PMT44190
      ID = NRMAX                                                        PMT44200
      DO 120 K=ID,JUPBND                                                PMT44210
         MAXERR = IORD(NRMAX)                                           PMT44220
         ERRMAX = ELIST(MAXERR)                                         PMT44230
         IF (DABS(BLIST(MAXERR)-ALIST(MAXERR)).GT.SMALL) GO TO 200      PMT44240
         NRMAX = NRMAX + 1                                              PMT44250
  120 CONTINUE                                                          PMT44260
C                                                                       PMT44270
C        PERFORM EXTRAPOLATION                                          PMT44280
C                                                                       PMT44290
  140 NUMRL2 = NUMRL2 + 1                                               PMT44300
      RLIST2(NUMRL2) = AREA                                             PMT44310
      CALL D01AJY(NUMRL2, RLIST2, RESEPS, ABSEPS, RES3LA, NRES)         PMT44320
      KTMIN = KTMIN + 1                                                 PMT44330
      IF (KTMIN.GT.5 .AND. ABSERR.LT.0.1D-02*ERRSUM) IER = 5            PMT44340
      IF (ABSEPS.GE.ABSERR) GO TO 160                                   PMT44350
      KTMIN = 0                                                         PMT44360
      ABSERR = ABSEPS                                                   PMT44370
      RESULT = RESEPS                                                   PMT44380
      CORREC = ERLARG                                                   PMT44390
      ERTEST = DMAX1(EPSABS,EPSREL*DABS(RESEPS))                        PMT44400
      IF (ABSERR.LE.ERTEST) GO TO 220                                   PMT44410
C                                                                       PMT44420
C        PREPARE  BISECTION OF THE SMALLEST INTERVAL                    PMT44430
C                                                                       PMT44440
  160 IF (NUMRL2.EQ.1) NOEXT = .TRUE.                                   PMT44450
      IF (IER.EQ.5) GO TO 220                                           PMT44460
      MAXERR = IORD(1)                                                  PMT44470
      ERRMAX = ELIST(MAXERR)                                            PMT44480
      NRMAX = 1                                                         PMT44490
      EXTRAP = .FALSE.                                                  PMT44500
      SMALL = SMALL*0.5D+00                                             PMT44510
      ERLARG = ERRSUM                                                   PMT44520
```

```
         GO TO 200
  180    SMALL = DABS(B-A)*0.375D+00
         ERLARG = ERRSUM
         ERTEST = ERRBND
         RLIST2(2) = AREA
  200 CONTINUE
C
C           SET  FINAL RESULT AND ERROR ESTIMATE
C           ------------------------------------
C
  220 IF (ABSERR.EQ.OFLOW) GO TO 280
      IF (IER+IERRO.EQ.0) GO TO 260
      IF (IERRO.EQ.3) ABSERR = ABSERR + CORREC
      IF (IER.EQ.0) IER = 3
      IF (RESULT.NE.0.D+00.AND .AREA. NE.0.D+00) GO TO 240
      IF (ABSERR.GT.ERRSUM) GO TO 280
      IF (AREA.EQ.0.D+00) GO TO 320
      GO TO 260
  240 IF (ABSERR/DABS(RESULT).GT.ERRSUM/DABS(AREA)) GO TO 280
C
C           TEST ON DIVERGENCY
C
  260 IF (KSGN.EQ.-1 .AND. DMAX1(DABS(RESULT),DABS(AREA)).LE.DEFABS*
     *0.1D-01) GO TO 320
      IF (0.1D-01.GT.(RESULT/AREA) .OR. (RESULT/AREA).GT.0.1D+03.OR.
     * ERRSUM.GT.DABS(AREA)) IER = 6
      GO TO 320
C
C           COMPUTE GLOBAL INTEGRAL SUM
C
  280 RESULT = 0.D+00
      DO 300 K=1,LAST
         RESULT = RESULT + RLIST(K)
  300 CONTINUE
      ABSERR = ERRSUM
  320 IF (IER.GT.2) IER = IER - 1
      IORD(1) = 4*LAST1
      RETURN
      END
C
C
C
      SUBROUTINE D01AJX(LIMIT, LAST, MAXERR, ERMAX, ELIST, IORD,LIORD,
     * NRMAX)
C                    SUBROUTINE D01AJX , PART OF PEM-2 (VERSION 84130).
C
C     MARK 8 RELEASE. NAG COPYRIGHT 1979
C     BASED ON QUADPACK ROUTINE ORDER
C     ******************************************************
C
C           PURPOSE
C              THIS ROUTINE MAINTAINS THE DESCENDING ORDERING
C              IN THE LIST OF THE LOCAL ERROR ESTIMATES
C              RESULTING FROM THE INTERVAL SUBDIVISION
C              PROCESS. AT EACH CALL TWO ERROR ESTIMATES
C              ARE INSERTED USING THE SEQUENTIAL SEARCH
C              METHOD . TOP-DOWN FOR THE LARGEST ERROR
C              ESTIMATE,  BOTTOM-UP FOR THE SMALLEST ERROR
C              ESTIMATE.
C
C           CALLING SEQUENCE
C              CALL D01AJX
C              (LIMIT,LAST,MAXERR,ERMAX,ELIST,IORD,LIORD,NRMAX)
C
C             PARAMETERS (MEANING AT OUTPUT)
C              LIMIT  - MAXIMUM NUMBER OF ERROR ESTIMATES THE LIST
C                       CAN CONTAIN
C
C              LAST   - NUMBER OF ERROR ESTIMATES CURRENTLY
C                       IN THE LIST. ELIST(LAST) CONTAINS
```

```
C                       THE SMALLEST ERROR ESTIMATE.                    PMT45220
C                                                                       PMT45230
C              MAXERR - MAXERR POINTS TO THE NRMAX-TH LARGEST ERROR    PMT45240
C                       ESTIMATE CURRENTLY IN THE LIST.                 PMT45250
C                                                                       PMT45260
C              ERMAX  - NRMAX-TH LARGEST ERROR ESTIMATE                 PMT45270
C                       ERMAX = ELIST(MAXERR)                           PMT45280
C                                                                       PMT45290
C              ELIST  - ARRAY OF DIMENSION LAST CONTAINING              PMT45300
C                       THE ERROR ESTIMATES                             PMT45310
C                                                                       PMT45320
C              IORD   - ARRAY CONTAINING POINTERS TO ELIST SO           PMT45330
C                       THAT IORD(1) POINTS TO THE LARGEST              PMT45340
C                       ERROR ESTIMATE,...,IORD(LAST) TO THE            PMT45350
C                       SMALLEST ERROR ESTIMATE                         PMT45360
C                                                                       PMT45370
C              LIORD  - DIMENSION OF IORD                               PMT45380
C                                                                       PMT45390
C              NRMAX  - MAXERR = IORD(NRMAX)                            PMT45400
C                                                                       PMT45410
C     *******************************************************           PMT45420
C                                                                       PMT45430
C     .. SCALAR ARGUMENTS ..                                            PMT45440
      DOUBLE PRECISION ERMAX                                            PMT45450
      INTEGER LAST, LIMIT, LIORD, MAXERR, NRMAX                         PMT45460
C     .. ARRAY ARGUMENTS ..                                             PMT45470
      DOUBLE PRECISION ELIST(LAST)                                      PMT45480
      INTEGER IORD(LIORD)                                               PMT45490
C     ..                                                                PMT45500
C     .. SCALARS IN COMMON ..                                           PMT45510
      INTEGER JUPBND                                                    PMT45520
C     ..                                                                PMT45530
C     .. LOCAL SCALARS ..                                               PMT45540
      DOUBLE PRECISION ERRMAX, ERRMIN                                   PMT45550
      INTEGER I, IBEG, IDO, ISUCC, J, JBND, K                           PMT45560
C     ..                                                                PMT45570
      COMMON /AD01AJ/ JUPBND                                            PMT45580
C                                                                       PMT45590
C            CHECK WHETHER THE LIST CONTAINS MORE THAN                  PMT45600
C            TWO ERROR ESTIMATES                                        PMT45610
C                                                                       PMT45620
      IF (LAST.GT.2) GO TO 20                                           PMT45630
      IORD(1) = 1                                                       PMT45640
      IORD(2) = 2                                                       PMT45650
      GO TO 180                                                         PMT45660
C                                                                       PMT45670
C           THIS PART OF THE ROUTINE IS ONLY EXECUTED                   PMT45680
C           IF, DUE TO A DIFFICULT INTEGRAND, SUBDIVISION               PMT45690
C           INCREASED THE ERROR ESTIMATE. IN THE NORMAL CASE            PMT45700
C           THE INSERT PROCEDURE SHOULD START AFTER THE                 PMT45710
C           NRMAX-TH LARGEST ERROR ESTIMATE.                            PMT45720
C                                                                       PMT45730
   20 ERRMAX = ELIST(MAXERR)                                            PMT45740
      IF (NRMAX.EQ.1) GO TO 60                                          PMT45750
      IDO = NRMAX - 1                                                   PMT45760
      DO 40 I=1,IDO                                                     PMT45770
         ISUCC = IORD(NRMAX-1)                                          PMT45780
         IF (ERRMAX.LE.ELIST(ISUCC)) GO TO 60                           PMT45790
         IORD(NRMAX) = ISUCC                                            PMT45800
         NRMAX = NRMAX - 1                                              PMT45810
   40 CONTINUE                                                          PMT45820
C                                                                       PMT45830
C           COMPUTE THE NUMBER OF ELEMENTS IN THE LIST TO               PMT45840
C           BE MAINTAINED IN DESCENDING ORDER. THIS NUMBER              PMT45850
C           DEPENDS ON THE NUMBER OF SUBDIVISIONS STILL                 PMT45860
C           ALLOWED                                                     PMT45870
C                                                                       PMT45880
   60 JUPBND = LAST                                                     PMT45890
      IF (LAST.GT.(LIMIT/2+2)) JUPBND = LIMIT + 3 - LAST                PMT45900
      ERRMIN = ELIST(LAST)                                              PMT45910
```

```
C
C          INSERT ERRMAX BY TRAVERSING THE LIST TOP-DOWN
C          STARTING COMPARISON FROM THE ELEMENT
C          ELIST(IORD(NRMAX+1))
C
      JBND = JUPBND - 1
      IBEG = NRMAX + 1
      IF (IBEG.GT.JBND) GO TO 100
      DO 80 I=IBEG,JBND
         ISUCC = IORD(I)
         IF (ERRMAX.GE.ELIST(ISUCC)) GO TO 120
         IORD(I-1) = ISUCC
   80 CONTINUE
  100 IORD(JBND) = MAXERR
      IORD(JUPBND) = LAST
      GO TO 180
C
C          INSERT ERRMIN BY TRAVERSING THE LIST BOTTOM-UP
C
  120 IORD(I-1) = MAXERR
      K = JBND
      DO 140 J=I,JBND
         ISUCC = IORD(K)
         IF (ERRMIN.LT.ELIST(ISUCC)) GO TO 160
         IORD(K+1) = ISUCC
         K = K - 1
  140 CONTINUE
      IORD(I) = LAST
      GO TO 180
  160 IORD(K+1) = LAST
C
C          SET MAXERR AND ERMAX
C
  180 MAXERR = IORD(NRMAX)
      ERMAX = ELIST(MAXERR)
      RETURN
      END
C
C
C
      SUBROUTINE D01AJY(N, EPSTAB, RESULT, ABSERR, RES3LA, NRES)
C                    SUBROUTINE D01AJY , PART OF PEM-2 (VERSION 84130).
C
C     MARK 8 RELEASE. NAG COPYRIGHT 1979
C     BASED ON QUADPACK ROUTINE EPSALG
C     *******************************************************
C
C           PURPOSE
C              THE ROUTINE TRANSFORMS A GIVEN SEQUENCE OF
C              APPROXIMATIONS, BY MEANS OF THE EPSILON
C              ALGORITHM OF P. WYNN.
C
C              AN ESTIMATE OF THE ABSOLUTE ERROR IS ALSO GIVEN.
C              THE CONDENSED EPSILON TABLE IS COMPUTED. ONLY THOSE
C              ELEMENTS NEEDED FOR THE COMPUTATION OF THE
C              NEXT DIAGONAL ARE PRESERVED.
C
C           CALLING SEQUENCE
C              CALL D01AJY (N,EPSTAB,RESULT,ABSERR,RES3LA,NRES)
C
C           PARAMETERS
C              N      - EPSTAB(N) CONTAINS THE NEW ELEMENT IN THE
C                       FIRST COLUMN OF THE EPSILON TABLE.
C
C              EPSTAB - ONE DIMENSIONAL ARRAY CONTAINING THE
C                       ELEMENTS OF THE TWO LOWER DIAGONALS OF
C                       THE TRIANGULAR EPSILON TABLE.
C                       THE ELEMENTS ARE NUMBERED STARTING AT THE
C                       RIGHT-HAND CORNER OF THE TRIANGLE.
C                       THE DIMENSION SHOULD BE AT LEAST N+2.
```

```
C
C              RESULT - RESULTING APPROXIMATION TO THE INTEGRAL
C
C              ABSERR - ESTIMATE OF THE ABSOLUTE ERROR COMPUTED FROM
C                       RESULT AND THE 3 PREVIOUS /RESULTS/
C
C              RES3LA - ARRAY CONTAINING THE LAST 3 /RESULTS/
C
C              NRES   - NUMBER OF CALLS TO THE ROUTINE
C                       (SHOULD BE ZERO AT FIRST CALL)
C
C     *****************************************************
C     .. SCALAR ARGUMENTS ..
      DOUBLE PRECISION ABSERR, RESULT
      INTEGER N, NRES
C     .. ARRAY ARGUMENTS ..
      DOUBLE PRECISION EPSTAB(52), RES3LA(3)
C     ..
C     .. LOCAL SCALARS ..
      DOUBLE PRECISION DELTA1, DELTA2, DELTA3, E0, E1, E1ABS, E2, E3,
     * EPMACH,EPSINF, ERR1, ERR2, ERR3, ERROR, OFLOW, RES, SS, TOL1,
     * TOL2,TOL3
      INTEGER I, IB2, IB, IE, IND, K1, K2, K3, LIMEXP, NEWELM, NUM
C     .. FUNCTION REFERENCES ..
      DOUBLE PRECISION X02AAF, X02ACF
C     ..
C
C            MACHINE DEPENDENT CONSTANTS
C            ---------------------------
C
C            /LIMEXP/ IS THE MAXIMUM NUMBER OF ELEMENTS THE EPSILON
C            TABLE CAN CONTAIN. IF THIS NUMBER IS REACHED, THE UPPER
C            DIAGONAL OF THE EPSILON TABLE IS DELETED.
C
      DATA LIMEXP /50/
      EPMACH = X02AAF()
      OFLOW = X02ACF()
C
C           LIST OF MAJOR VARIABLES
C           -----------------------
C
C           E0     - THE 4 ELEMENTS ON WHICH THE
C           E1       COMPUTATION OF A NEW ELEMENT IN
C           E2       THE EPSILON TABLE IS BASED
C           E3                 E0
C                        E3    E1    NEW
C                              E2
C           NEWELM - NUMBER OF ELEMENTS TO BE COMPUTED IN THE NEW
C                    DIAGONAL
C           ERROR  - ERROR = ABS(E1-E0)+ABS(E2-E1)+ABS(NEW-E2)
C           RESULT - THE ELEMENT IN THE NEW DIAGONAL WITH LEAST
C                    ERROR
C
      NRES = NRES + 1
      ABSERR = OFLOW
      RESULT = EPSTAB(N)
      IF (N.LT.3) GO TO 200
      EPSTAB(N+2) = EPSTAB(N)
      NEWELM = (N-1)/2
      EPSTAB(N) = OFLOW
      NUM = N
      K1 = N
      DO 80 I=1,NEWELM
         K2 = K1 - 1
         K3 = K1 - 2
         RES = EPSTAB(K1+2)
         E0 = EPSTAB(K3)
         E1 = EPSTAB(K2)
         E2 = RES
         E1ABS = DABS(E1)
         DELTA2 = E2 - E1
         ERR2 = DABS(DELTA2)
```

```
        TOL2 = DMAX1(DABS(E2),E1ABS)*EPMACH
        DELTA3 = E1 - E0
        ERR3 = DABS(DELTA3)
        TOL3 = DMAX1(E1ABS,DABS(E0))*EPMACH
        IF (ERR2.GT.TOL2 .OR. ERR3.GT.TOL3) GO TO 20
C
C           IF E0, E1 AND E2 ARE EQUAL TO WITHIN MACHINE
C           ACCURACY, CONVERGENCE IS ASSUMED
C           RESULT = E2
C           ABSERR = ABS(E1-E0)+ABS(E2-E1)
C
        RESULT = RES
        ABSERR = ERR2 + ERR3
        GO TO 200
   20   E3 = EPSTAB(K1)
        EPSTAB(K1) = E1
        DELTA1 = E1 - E3
        ERR1 = DABS(DELTA1)
        TOL1 = DMAX1(E1ABS,DABS(E3))*EPMACH
C
C           IF TWO ELEMENTS ARE VERY CLOSE TO EACH OTHER, OMIT
C           A PART OF THE TABLE BY ADJUSTING THE VALUE OF N
C
        IF (ERR1.LT.TOL1 .OR. ERR2.LT.TOL2 .OR. ERR3.LT.TOL3) GOTO 40
        SS = 0.1D+01/DELTA1 + 0.1D+01/DELTA2 - 0.1D+01/DELTA3
        EPSINF = DABS(SS*E1)
C
C           TEST TO DETECT IRREGULAR BEHAVIOUR IN THE TABLE, AND
C           EVENTUALLY OMIT A PART OF THE TABLE ADJUSTING THE VALUE
C           OF N
C
        IF (EPSINF.GT.0.1D-03) GO TO 60
   40   N = I + I - 1
        GO TO 100
C
C           COMPUTE A NEW ELEMENT AND EVENTUALLY ADJUST
C           THE VALUE OF RESULT
C
   60   RES = E1 + 0.1D+01/SS
        EPSTAB(K1) = RES
        K1 = K1 - 2
        ERROR = ERR2 + DABS(RES-E2) + ERR3
        IF (ERROR.GT.ABSERR) GO TO 80
        ABSERR = ERROR
        RESULT = RES
   80 CONTINUE
C
C           SHIFT THE TABLE
C
  100 IF (N.EQ.LIMEXP) N = 2*(LIMEXP/2) - 1
      IB = 1
      IF ((NUM/2)*2.EQ.NUM) IB = 2
      IE = NEWELM + 1
      DO 120 I=1,IE
         IB2 = IB + 2
         EPSTAB(IB) = EPSTAB(IB2)
         IB = IB2
  120 CONTINUE
      IF (NUM.EQ.N) GO TO 160
      IND = NUM - N + 1
      DO 140 I=1,N
         EPSTAB(I) = EPSTAB(IND)
         IND = IND + 1
  140 CONTINUE
  160 IF (NRES.GE.4) GO TO 180
      RES3LA(NRES) = RESULT
      ABSERR = OFLOW
      GO TO 200
C
C           COMPUTE ERROR ESTIMATE
```

```
C
  180 ABSERR = DABS(RESULT-RES3LA(3)) + DABS(RESULT-RES3LA(2)) +
     *DABS(RESULT-RES3LA(1))
      RES3LA(1) = RES3LA(2)
      RES3LA(2) = RES3LA(3)
      RES3LA(3) = RESULT
  200 ABSERR = DMAX1(ABSERR,5.0D+00*EPMACH*DABS(RESULT))
      RETURN
      END
C
C
C
      SUBROUTINE D01AJZ(F, A, B, RESULT, ABSERR, RESABS, RESASC)
C                 SUBROUTINE D01AJZ , PART OF PEM-2 (VERSION 84130).
C
C     MARK 8 RELEASE. NAG COPYRIGHT 1979
C     BASED ON QUADPACK ROUTINE QUARUL
C     ****************************************************
C
C           PURPOSE
C              TO COMPUTE I = INTEGRAL OF F OVER (A,B), WITH ERROR
C                             ESTIMATE
C                         J = INTEGRAL OF ABS(F) OVER (A,B)
C
C           CALLING SEQUENCE
C              CALL D01AJZ (F,A,B,RESULT,ABSERR,RESABS,RESASC)
C
C           PARAMETERS
C              F      - FUNCTION SUBPROGRAM DEFINING THE INTEGRAND
C                       FUNCTION F(X). THE ACTUAL NAME FOR F NEEDS
C                       TO BE DECLARED E X T E R N A L IN THE
C                       CALLING PROGRAM
C
C              A      - LOWER LIMIT OF INTEGRATION
C
C              B      - UPPER LIMIT OF INTEGRATION
C
C              RESULT - APPROXIMATION TO THE INTEGRAL I.
C                       RESULT IS CALCULATED BY APPLYING
C                       THE 21-POINT GAUSS-KRONROD RULE
C                       (RESK), OBTAINED BY OPTIMAL
C                       ADDITION OF ABSCISSAE TO THE
C                       10-POINT GAUSS  RULE (RESG).
C
C              ABSERR - ESTIMATE OF THE MODULUS OF THE
C                       ABSOLUTE ERROR, WHICH SHOULD NOT
C                       EXCEED ABS(I-RESULT)
C              RESABS - APPROXIMATION TO THE INTEGRAL J
C
C              RESASC - APPROXIMATION TO THE INTEGRAL OF
C                       ABS(F-I/(B-A)) OVER (A,B)
C
C     ****************************************************
C     .. SCALAR ARGUMENTS ..
      DOUBLE PRECISION A, ABSERR, B, RESABS, RESASC, RESULT
C     .. FUNCTION ARGUMENTS ..
      DOUBLE PRECISION F
C     ..
C     .. LOCAL SCALARS ..
      DOUBLE PRECISION ABSC, CENTRE, DHLGTH, EPMACH, FC, FSUM, FVAL1,
     * FVAL2,HLGTH, RESG, RESK, RESKH, UFLOW
      INTEGER J
C     .. LOCAL ARRAYS ..
      DOUBLE PRECISION FV1(10), FV2(10), WG(10), WGK(11), XGK(11)
C     .. FUNCTION REFERENCES ..
      DOUBLE PRECISION X02AAF, X02ABF
C     ..
C
C           THE ABSCISSAE AND WEIGHTS ARE GIVEN FOR THE
C           INTERVAL (-1,1) . BECAUSE OF SYMMETRY ONLY THE
```

```
C           POSITIVE ABSCISSAE AND THEIR CORRESPONDING
C           WEIGHTS ARE GIVEN.
C           XGK    - ABSCISSAE OF THE 21-POINT GAUSS-KRONROD RULE
C                    XGK(2), XGK(4), .... ABSCISSAE OF THE 10-POINT
C                    GAUSS RULE
C                    XGK(1), XGK(3), .... ABSCISSAE WHICH
C                    ARE OPTIMALLY ADDED TO THE 10-POINT
C                    GAUSS RULE
C           WGK    - WEIGHTS OF THE 21-POINT GAUSS-KRONROD RULE
C           WG     - WEIGHTS OF THE 10-POINT GAUSS RULE,
C                    CORRESPONDING TO THE ABSCISSAE XGK(2),
C                    XGK(4), ... WG(1), WG(3), ... ARE SET
C                    TO ZERO.
C
      DATA XGK(1), XGK(2), XGK(3), XGK(4), XGK(5), XGK(6), XGK(7),XGK(8)
     *, XGK(9), XGK(10), XGK(11) /0.995657163025808080735527280 7D+00,
     *0.973906528517171720077964012 1D+00,
     *0.930157491355708226001207180 1D+00,
     *0.865063366688984510732096688 4D+00,
     *0.780817726586416897063717578 3D+00,
     *0.679409568299024406234327365 1D+00,
     *0.562757134668604683339000099 3D+00,
     *0.433395394129247190799265943 2D+00,
     *0.294392862701460198131126603 1D+00,
     *0.148874338981631210884826001 1D+00,0.0D0/
      DATA WGK(1), WGK(2), WGK(3), WGK(4), WGK(5), WGK(6), WGK(7),WGK(8)
     *, WGK(9), WGK(10), WGK(11) /0.116946388673718742780643960 6D-01,
     *0.325581623079647274788189724 6D-01,
     *0.547558965743519960313813002 4D-01,
     *0.750396748109199527670431409 2D-01,
     *0.931254545836976055350654650 8D-01,
     *0.109387158802297641899210590 3D+00,
     *0.123491976262065851077958109 8D+00,
     *0.134709217311473325928054001 8D+00,
     *0.142775938577060080797094273 1D+00,
     *0.147739104901338491374841516 0D+00,
     *0.149445554002916905664936468 4D+00/
      DATA WG(1), WG(2), WG(3), WG(4), WG(5), WG(6), WG(7), WG(8),WG(9),
     * WG(10) /0.0D0,0.666713443086881375935688098 9D-01,0.0D0,
     *0.149451349150580593145776339 7D+00,0.0D0,
     *0.219086362515982043995534934 2D+00,0.0D0,
     *0.269266719309996355091226921 6D+00,0.0D0,
     *0.295524224714752870173892994 7D+00/
      EPMACH = X02AAF()
      UFLOW = X02ABF()
C
C           LIST OF MAJOR VARIABLES
C           -----------------------
C
C           CENTRE - MID POINT OF THE INTERVAL
C           HLGTH  - HALF LENGTH OF THE INTERVAL
C           ABSC   - ABSCISSA
C           FVAL*  - FUNCTION VALUE
C           RESG   - 10-POINT GAUSS FORMULA
C           RESK   - 21-POINT GAUSS-KRONROD FORMULA
C           RESKH  - APPROXIMATION TO MEAN VALUE OF F OVER
C                    (A,B), I.E. TO I/(B-A)
C
      CENTRE = 0.5D+00*(A+B)
      HLGTH = 0.5D+00*(B-A)
      DHLGTH = DABS(HLGTH)
C
C           COMPUTE THE 21-POINT GAUSS-KRONROD APPROXIMATION TO
C           THE INTEGRAL, AND ESTIMATE THE ABSOLUTE ERROR
C
      RESG = 0.0D+00
      FC = F(CENTRE)
      RESK = WGK(11)*FC
      RESABS = DABS(RESK)
      DO 20 J=1,10
        ABSC = HLGTH*XGK(J)
        FVAL1 = F(CENTRE-ABSC)
        FVAL2 = F(CENTRE+ABSC)
        FV1(J) = FVAL1
        FV2(J) = FVAL2
        FSUM = FVAL1 + FVAL2
        RESG = RESG + WG(J)*FSUM
        RESK = RESK + WGK(J)*FSUM
        RESABS = RESABS + WGK(J)*(DABS(FVAL1)+DABS(FVAL2))
   20 CONTINUE
      RESKH = RESK*0.5D+00
      RESASC = WGK(11)*DABS(FC-RESKH)
      DO 40 J=1,10
        RESASC = RESASC + WGK(J)*(DABS(FV1(J)-RESKH)+DABS(FV2(J)-RESKH)
     *    )
   40 CONTINUE
      RESULT = RESK*HLGTH
      RESABS = RESABS*DHLGTH
      RESASC = RESASC*DHLGTH
      ABSERR = DABS((RESK-RESG)*HLGTH)
      IF (RESASC.NE.0.D+00) ABSERR = RESASC*DMIN1(0.1D+01,(0.2D+03*
     *ABSERR/RESASC)**1.5D0)
      IF (RESABS.GT.UFLOW/(0.5D+02*EPMACH)) ABSERR =DMAX1(EPMACH*RESABS*
     *0.5D+02,ABSERR)
      RETURN
      END
C
C
C
      INTEGER FUNCTION P01AAF(IFAIL, ERROR, SRNAME)
C                      FUNCTION P01AAF , PART OF PEM-2 (VERSION 84130).
C
C     MARK 1 RELEASE.  NAG COPYRIGHT 1971
C     MARK 3 REVISED
C     MARK 4A REVISED, IER-45
C     MARK 4.5 REVISED
C     MARK 7 REVISED (DEC 1978)
C     RETURNS THE VALUE OF ERROR OR TERMINATES THE PROGRAM.
      INTEGER ERROR, IFAIL, NOUT
C$P 1
      DOUBLE PRECISION SRNAME
C     TEST IF NO ERROR DETECTED
      IF (ERROR.EQ.0) GO TO 20
C     DETERMINE OUTPUT UNIT FOR MESSAGE
      CALL X04AAF (0,NOUT)
C     TEST FOR SOFT FAILURE
      IF (MOD(IFAIL,10).EQ.1) GO TO 10
C     HARD FAILURE
      WRITE (NOUT,99999) SRNAME, ERROR
C     STOPPING MECHANISM MAY ALSO DIFFER
      CALL WAUDIT
      STOP
C     SOFT FAIL
C     TEST IF ERROR MESSAGES SUPPRESSED
   10 IF (MOD(IFAIL/10,10).EQ.0) GO TO 20
      WRITE (NOUT,99999) SRNAME, ERROR
   20 P01AAF = ERROR
      RETURN
99999 FORMAT (1H0, 38HERROR DETECTED BY NAG LIBRARY ROUTINE , A8,
     * 11H - IFAIL = , I5//)
      END
C
C
C
      DOUBLE PRECISION FUNCTION X02AAF()
C                      FUNCTION X02AAF , PART OF PEM-2 (VERSION 84130).
C
C     NAG COPYRIGHT 1975
C     MARK 4.5 RELEASE
C
C     * EPS *
```

```
C                                                                                 PMT50070
C     UNIVAC DOUBLE PRECISION VERSION                                             PMT50080
C                                                                                 PMT50090
C     RETURNS THE VALUE EPS WHERE EPS IS THE SMALLEST POSITIVE                    PMT50100
C     NUMBER SUCH THAT 1.0 + EPS > 1.0                                            PMT50120
C                                                                                 PMT50130
C     FOR ICL 1900                                                                PMT50140
C     X02AAF = 2.0**(-37.0)                                                       PMT50150
C                                                                                 PMT50155
C     FOR IBM 360/370                                                             PMT50160
C     X02AAF = 2.0D0**(-52.0D0)                                                   PMT50170
C                                                                                 PMT50175
      DOUBLE PRECISION Z                                                          PMT50180
C                                                                                 PMT50185
C     FOR IBM-3033                                                                PMT50190
C     DATA Z/Z3410000000000000/                                                   PMT50200
C                                                                                 PMT50205
C     FOR UNIVAC-1100                                                             PMT50210
      DIMENSION ZZ(2)                                                             PMT50220
      EQUIVALENCE (ZZ(1),Z)                                                       PMT50230
      DATA ZZ /017141000000,000000000000/                                         PMT50240
      X02AAF = Z                                                                  PMT50250
      RETURN                                                                      PMT50260
      END                                                                         PMT50270
C
C                                                                                 PMT50280
C                                                                                 PMT50290
      DOUBLE PRECISION FUNCTION X02ABF()                                          PMT50300
C                         FUNCTION X02ABF , PART OF PEM-2 (VERSION 84130). PMT50310
C                                                                                 PMT50320
C     NAG COPYRIGHT 1975                                                          PMT50330
C     MARK 4.5 RELEASE                                                            PMT50340
C                                                                                 PMT50350
C     * RMIN *                                                                    PMT50360
C                                                                                 PMT50370
C     UNIVAC DOUBLE PRECISION VERSION                                             PMT50380
C                                                                                 PMT50390
C     RETURNS THE VALUE OF THE SMALLEST POSITIVE REAL FLOATING-                   PMT50400
C     POINT NUMBER EXACTLY REPRESENTABLE ON THE COMPUTER                          PMT50410
C                                                                                 PMT50420
C     FOR ICL 1900                                                                PMT50430
C     X02ABF = 2.0**(-257.0)                                                      PMT50440
C                                                                                 PMT50445
C     FOR IBM 360/370                                                             PMT50450
C     X02ABF = 16.0D0**(-65.0D0)                                                  PMT50460
C                                                                                 PMT50465
      DOUBLE PRECISION Z                                                          PMT50470
C                                                                                 PMT50475
C     FOR IBM-3033                                                                PMT50480
C     DATA Z/Z0010000000000000/                                                   PMT50490
C                                                                                 PMT50495
C     FOR UNIVAC-1100                                                             PMT50500
      DIMENSION ZZ(2)                                                             PMT50510
      EQUIVALENCE (ZZ(1),Z)                                                       PMT50520
      DATA ZZ /000011000000,000000000000/                                         PMT50530
      X02ABF = Z                                                                  PMT50540
      RETURN                                                                      PMT50550
      END                                                                         PMT50560
C
C                                                                                 PMT50570
C                                                                                 PMT50580
      DOUBLE PRECISION FUNCTION X02ACF()                                          PMT50590
C                         FUNCTION X02ACF , PART OF PEM-2 (VERSION 84130). PMT50600
C                                                                                 PMT50610
C     NAG COPYRIGHT 1975                                                          PMT50620
C     MARK 4.5 RELEASE                                                            PMT50630
C                                                                                 PMT50640
C     * RMAX *                                                                    PMT50650
C                                                                                 PMT50660
C     UNIVAC DOUBLE PRECISION VERSION                                             PMT50670
```

```
C
C                                                                        PMT50680
C     RETURNS THE VALUE OF THE LARGEST POSITIVE REAL  FLOATING-          PMT50690
C     POINT NUMBER REPRESENTABLE ON THE COMPUTER                         PMT50700
C                                                                        PMT50705
C     FOR ICL 1900                                                       PMT50710
C     X02ACF = (2.0 - 2.0**(-36.0))*2.0**254.0                           PMT50720
C                                                                        PMT50725
C     FOR IBM 360/370                                                    PMT50730
C     X02ACF = (1.0D0-16.0D0**(-14.0D0))*16.0D0**63.0D0                  PMT50740
      DOUBLE PRECISION Z                                                 PMT50745
C                                                                        PMT50750
C     FOR IBM-3033                                                       PMT50755
C     DATA Z/Z7FFFFFFFFFFFFFFF/                                          PMT50760
C                                                                        PMT50770
C     FOR UNIVAC-1100                                                    PMT50775
      DIMENSION ZZ(2)                                                    PMT50780
      EQUIVALENCE (ZZ(1),Z)                                              PMT50790
      DATA ZZ /0377777777777,0777777777777/                              PMT50800
      X02ACF = Z                                                         PMT50810
      RETURN                                                             PMT50820
      END                                                                PMT50830
C                                                                        PMT50840
C
C                                                                        PMT50850
      SUBROUTINE X04AAF(I,NERR)                                          PMT50860
C                   SUBROUTINE X04AAF , PART OF PEM-2 (VERSION 84130).   PMT50870
C                                                                        PMT50880
C     MARK 7 RELEASE. NAG COPYRIGHT 1978                                 PMT50890
C     MARK 7C REVISED IER-190 (MAY 1979)                                 PMT50900
C     IF I = 0, SETS NERR TO CURRENT ERROR MESSAGE UNIT NUMBER           PMT50910
C     (STORED IN NERR1).                                                 PMT50920
C     IF I = 1, CHANGES CURRENT ERROR MESSAGE UNIT NUMBER TO             PMT50930
C     VALUE SPECIFIED BY NERR.                                           PMT50940
C                                                                        PMT50950
C     *** NOTE ***                                                       PMT50960
C     THIS ROUTINE ASSUMES THAT THE VALUE OF NERR1 IS SAVED              PMT50970
C     BETWEEN CALLS.  IN SOME IMPLEMENTATIONS IT MAY BE                  PMT50980
C     NECESSARY TO STORE NERR1 IN A LABELLED COMMON                      PMT50990
C     BLOCK /AX04AA/ TO ACHIEVE THIS.                                    PMT51000
C                                                                        PMT51010
C     .. SCALAR ARGUMENTS ..                                             PMT51020
      INTEGER I, NERR                                                    PMT51030
C     ..                                                                 PMT51040
C     .. LOCAL SCALARS ..                                                PMT51050
      INTEGER NERR1                                                      PMT51060
C     ..                                                                 PMT51070
      DATA NERR1 /6/                                                     PMT51080
      IF (I.EQ.0) NERR = NERR1                                           PMT51090
      IF (I.EQ.1) NERR1 = NERR                                           PMT51100
      RETURN                                                             PMT51110
      END                                                                PMT51120
C                                                                        PMT51130
      SUBROUTINE WIND(UA,PWR,HQ,UPL)                                     PMT51140
C                   SUBROUTINE WIND   , PART OF PEM-2 (VERSION 84130)    PMT51150
C                                                                        PMT51160
C                                                                        PMT51170
C  SUBROUTINE WIND DETERMINES THE WIND SPEED AT SOURCE HEIGHT            PMT51180
C   ACCORDING TO THE WIND PROFILE POWER LAW.                             PMT51190
C                                                                        PMT51200
C    UA = ANEMOMETER WIND SPEED (M/S)                                    PMT51210
C    PWR = EXPONENT OF POWER LAW WIND PROFILE                            PMT51220
C    HQ = SOURCE HEIGHT (M)                                              PMT51230
C    UPL = OUTPUT WIND SPEED AT SOURCE HEIGHT (M/S)                      PMT51240
C    HA = ANEMOMETER HEIGHT (M)                                          PMT51250
C    HMIN = WIND SPEED HELD CONSTANT BELOW THIS HEIGHT (M)               PMT51260
C    HMAX = WIND SPEED CONSTANT ABOVE THIS HEIGHT (M)                    PMT51270
C    UMIN = WIND SPEED NOT ALLOWED LESS THAN THIS VALUE (M/S)            PMT51280
C                                                                        PMT51290
C    IUFLG = WIND SPEED FLAG INDICATOR                                   PMT51300
```

```
C       0  -  NORMAL COMPUTATION                                        PMT51310
C       1  -  WIND SPEED SET AT VALUE AT HMIN                           PMT51320
C       2  -  WIND SPEED SET AT VALUE AT HMAX                           PMT51330
C       3  -  WIND SPEED SET AT UMIN VALUE                              PMT51340
C                                                                       PMT51350
C                                                                       PMT51360
      COMMON/PARM7A/HA,P1(6)                                            PMT51370
      COMMON/WND/HMIN,HMAX,UMIN,IUFLG                                   PMT51380
C                                                                       PMT51390
C     DEFAULT VALUES FOR HA, HMIN, HMAX, AND UMIN WERE SET              PMT51400
C     IN SUBROUTINE INMOD AS 10., 10., 200., AND 1. RESPECTIVELY,       PMT51410
C     UNLESS DEFINED ON THE INPUT CARD #7.                              PMT51420
C                                                                       PMT51430
      IF(HQ.LT.HMAX) THEN                                               PMT51440
      IF(HQ.GT.HMIN) THEN                                               PMT51450
      UPL=UA*((HQ/HA)**PWR)                                             PMT51460
      IUFLG=0                                                           PMT51470
      ELSE                                                              PMT51480
      UPL=UA*((HMIN/HA)**PWR)                                           PMT51490
      IUFLG=1                                                           PMT51500
      END IF                                                            PMT51510
      ELSE                                                              PMT51520
      UPL=UA*((HMAX/HA)**PWR)                                           PMT51530
      IUFLG=2                                                           PMT51540
      END IF                                                            PMT51550
      IF(UPL.LT.UMIN) THEN                                              PMT51560
      UPL=UMIN                                                          PMT51570
      IUFLG=3                                                           PMT51580
      END IF                                                            PMT51590
      RETURN                                                            PMT51600
      END                                                               PMT51610
```

Date ________________

Return form to;

James M. Godowitch
Meteorology and Assessment Division (MD-80)
U.S. Environmental Protection Agency
Research Triangle Park, NC 27711

I wish to receive future revisions to the PEM-2 User Guide.

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